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Technical

Information for

Problem

Spills

POTASSIUM CHLORIDE

March 1985

Canada

86-03103/

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

The Environmental and Technical Information for Problem Spills (EnviroTIPS) Manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The report has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

EnviroTIPS manuals are available from

Publications Section
Environmental Protection Service
Environment Canada
Ottawa, Ontario
CANADA
K1A 1C8

POTASSIUM CHLORIDE (POTASH)

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Ottawa, Ontario

March 1985

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Cat. No. En 48-10/35-1985E
ISBN 0-662-13984-4
BEAUREGARD PRESS LIMITED

FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals that are spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of EnviroTIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that they are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation and Waterloo Engineering Limited.

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1 SUMMARY

POTASSIUM CHLORIDE (Potash, KCl)

White to pinkish granules or powder, odourless

SYNONYMS

Muriate of Potash
Note: "Potash" often refers to potassium hydroxide or potassium compounds in general. Because the major source of potasslum is now potassium chloride, the term now more commonly refers to potassium chloride.

IDENTIFICATION NUMBERS

UN No. No hazard label required; CAS No. 7447-40-7; STCC No. Not required

GRADES & PURITIES

Soluble, 98.99 percent KCl
Refined, 99.95 percent KCl
Granular, 95.8 percent KCl
Coarse, 96.6 percent KCl
Standard, 95.8 percent KCl
Special, 95.8 percent KCl

IMMEDIATE CONCERNS

Fire: Not combustible

Human Health: Low toxicity by ingestion

Environmental: Harmful to aquatic life in high concentration

PHYSICAL PROPERTY DATA

State (15°C, 1 atm): solid
Boiling Point: 1411°C
Melting Point: 771 to 776°C
Flammability: not combustible
Specific Gravity: 1.988 (25°C)

Solubility (in water): 34.4 g/100 g (20°C)
Behaviour (in water): sinks and mixes; no reaction

ENVIRONMENTAL CONCERNS

Potassium chloride is toxic to aquatic life in high concentrations, generally over 1000 ppm. It does not have bioaccumulation and food chain contamination potential. Although it does not biodegrade, potassium is a nutrient and will be consumed by organisms.

HUMAN HEALTH

TLV® (as a nuisance dust): 10 mg/m^3 total dust or 5 mg/m^3 of respirable dust

Exposure Effects

Inhalation of dust: Slight irritation of the nose, sneezing

Ingestion: Nausea, vomiting, diarrhea, gastrointestinal tract irritation, abdominal discomfort, and generalized weakness. Large doses may cause mental confusion, hypotension, flaccid paralysis, cardiac arrhythmia and heart block, and possibly death

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Notify manufacturer. Stop the flow and contain spill, if safe to do so. Keep contaminated water from entering sewers or watercourses.

Fire Control

Not combustible. Use foam, dry chemical, carbon dioxide, water spray or fog to extinguish fires involving potash.

COUNTERMEASURES

Emergency Control Procedures

Soil: Shovel solid material into containers for recovery or disposal

Water: Contain by damming, water diversion or natural barriers. Remove contaminated water for treatment, if possible

2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

Appearance	Clear to white, often pinkish powder or granules
Usual shipping state	Solid
Physical state at 15°C, 1 atm	Solid
Melting point	771-776°C (JANAF 1971; Kirk-Othmer 1982)
Boiling point	1411°C (CRC 1980)

Densities

Density	1.987 g/cm^3 (20°C) (Ullmann 1975)
Specific gravity	1.988 (25°C) (Perry 1973)
Bulk density	Granular: 1.056-1.088 g/cm^3 (Kirk-Othmer 1982)
	Agricultural: 1.104-1.152 g/cm^3 (Kirk-Othmer 1982)

Fire Properties

Flammability	Not flammable or combustible (Kerr-McGee Bulletin)
Behaviour in a fire	Does not support combustion (Kerr-McGee Bulletin)

Other Properties

Molecular weight of pure substance	74.557 (Ullmann 1975)
Constituent component of typical commercial grade	95.8-98.99 percent KCl, remainder Na, NaCl and H_2O (PCS 1982)
Refractive index	1.490 (CRC 1980)
Viscosity	1.04 mPa•s (24 percent solution, 20°C) (CRC 1980)
Vapour pressure	0.13 kPa (865°C) (Bailar 1973)
Liquid interfacial tension with air	0.078 N/m (20°C, 24 percent solution) (CRC 1980)
Latent heat of fusion	25.5 kJ/mole (at melting point) (Kerr-McGee Bulletin)
Lattice energy of crystal	702.8 kJ/mole (Bailar 1973)
Latent heat of vaporization	162.5 kJ/mole (at boiling point) (Perry 1973)
Heat of formation	-436.7 kJ/mole (25°C) (JANAF 1971)

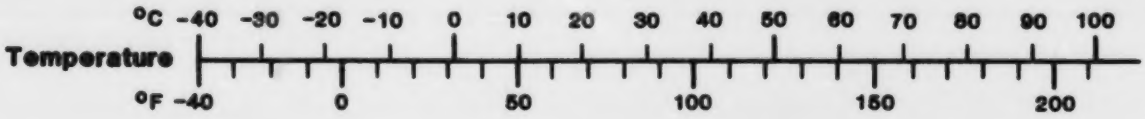
Entropy	82.65 J/(mole•K) (Ullmann 1975)
Ionization potential	8.0–10.1 eV (Rosenstock 1977)
Heat of solution	-17.5 kJ/mole (18°C) (Kerr-McGee Bulletin)
Critical temperature	2614°C (Bailar 1973)
Heat capacity	
constant pressure (C_p)	51.29 J/(mole•°C) (25°C) (JANAF 1971)
Coefficient of thermal expansion	0.0337 x 10^{-3}/°C (solid at 15-25°C) (Ullmann 1975)
	0.353 x 10^{-3}/°C (24 percent solution, 20°C) (Lange's Handbook 1979)
Thermal conductivity	0.069 J/(s•cm•°C) (0°C) (Lange's Handbook 1979)
pH of aqueous solution	6.4 (1 percent solution); 7.3 (10 percent solution) (Kerr-McGee MSI 1980; Kerr-McGee Bulletin)
Eutectic compositions	19.75 percent aqueous solution (f.p.-11.1°C) (Lange's Handbook 1979)
Dielectric constant	4.68 (Ullmann 1975)
Solubility	
In water	28.0 g/100 g (21.9 percent, 0°C), 34.4 g/100 g (25.6 percent, 20°C), 40.3 g/100 g (28.7 percent, 40°C) (Linke 1965)
In other common materials	Slightly soluble in ethanol; soluble in diethyl ether, glycerin and alkalis (CRC 1980)
	The solubility in a number of materials is as follows (Ullmann 1975)

Material	Solubility (wt %)	Temperature (°C)
Liquid Ammonia	0.13	0
Methanol	0.53	25
Ethanol	0.29	25
Ethylene Glycol	4.92	25
Glycerin	3.59	15
Acetic Acid	0.20	24

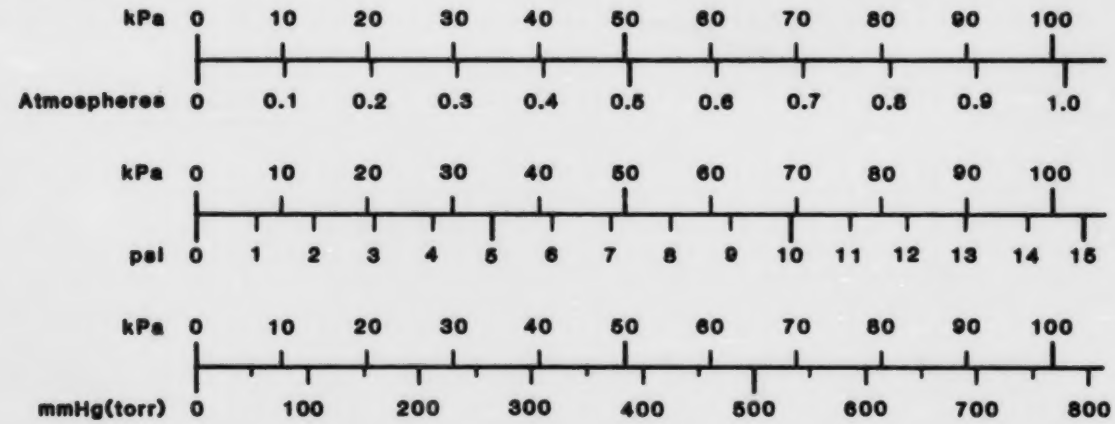
TABLE 1

POTASSIUM CHLORIDE (potash)

CONVERSION NOMOGRAMS



Pressure 1 kPa = 1 000 Pa



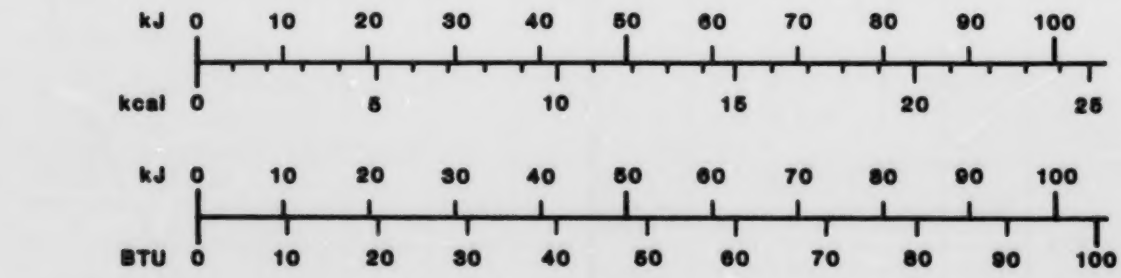
Viscosity

Dynamic 1 Pa·s = 1 000 centipoise (cP)

Kinematic 1 m^2/s = 1,000 000 centistokes (cSt)

Concentration (in water)
1 ppm ≅ 1 mg/L

Energy (heat) 1 kJ = 1 000 J



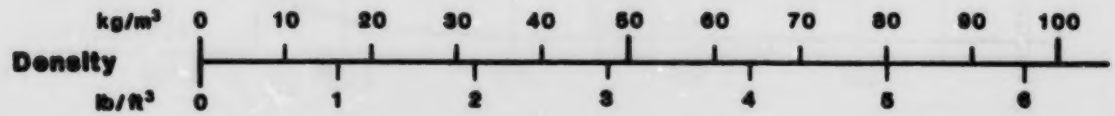


FIGURE 1

POTASSIUM CHLORIDE (potash)

SOLUBILITY IN WATER VS TEMPERATURE

Reference: Kerr–McGee Bulletin

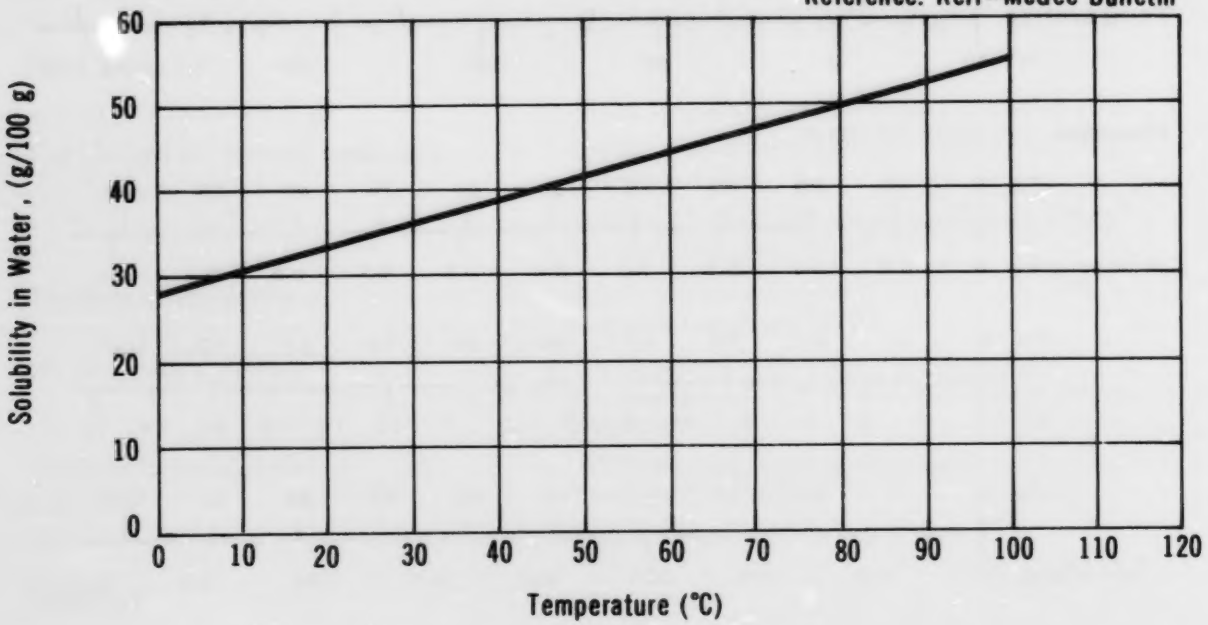
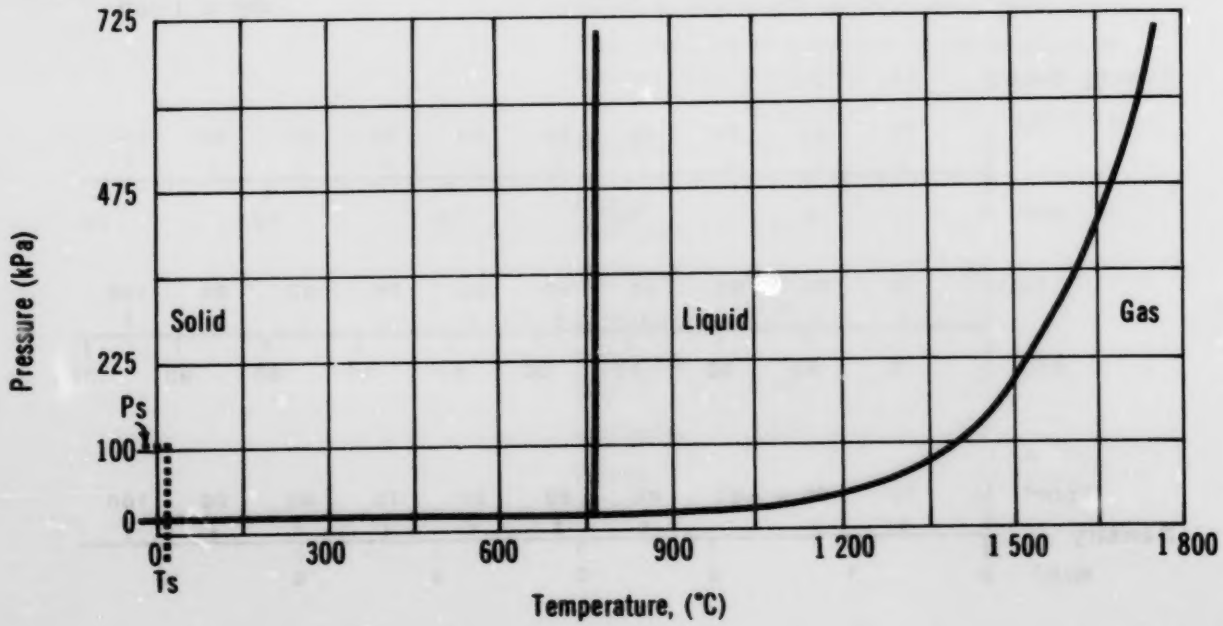


FIGURE 2

POTASSIUM CHLORIDE (potash)

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 Grades, Purities

The refined ore of KCl is variously referred to as potassium chloride, muriate of potash, or potash. The latter is most common and is also used to denote the potassium oxide (K_2O) equivalent of potassium chloride or other potassium-containing fertilizers. Potassium oxide (K_2O) does not exist but use of this terminology has been traditional and still continues. In pure form, potassium chloride contains 63.2 percent K_2O equivalent.

Potash is sold in several grades corresponding to purity and granule size (Kirk-Othmer 1982; PCS 1982; FC 1981):

Grade	Mesh Size	Percent KCl	Purity (as percent K_2O)
Soluble (Agricultural white)	40 x 100	98.99	62.5
Refined	-	99.95	63.1
Granular	6 x 20	95.80	60.5
Coarse	10 x 28	96.60	61.6
Standard	14 x 65	95.80	60.5
Special (Suspension)	35 x 150	95.80	60.5

3.2 Domestic Manufacturers (Corpus 1984; CBG 1980; CCPA 1981)

These are corporate headquarters' addresses and are not intended as spill response contacts.

Central Canada Potash, Subsidiary
of Noranda Mines Ltd.
P.O. Box 45, Commerce Court West
Toronto, Ontario
M5L 1B6
(416) 867-7111

Cominco Ltd.
200 Granville Street
Vancouver, British Columbia
V6C 2R2
(604) 682-0611

International Minerals & Chemical
Corp. (Canada) Ltd.
P.O. Box 310
Esterhazy, Saskatchewan
S0A 0X0
(306) 745-3931

Kalium Chemicals, Division of PPG
Industries Canada Ltd.
400 Bank of Canada Building
Regina, Saskatchewan
S4P 0M9
(306) 352-8691

Potash Corporation of America
Division of Ideal Basic Industries Inc.
P.O. Box 509
Saskatoon, Saskatchewan
S7K 3L6
(306) 374-4800

Potash Corporation of Saskatchewan
410-22nd Street East
Saskatoon, Saskatchewan
S7K 5T7
(306) 664-5530

3.3 Other Suppliers (Corpus 1984; CBG 1980; Scott 1979)

Canada Colours and Chemicals Ltd.
80 Scarsdale Road
Don Mills, Ontario
M3B 2R7
(416) 924-6831

Mallinckrodt Canada Inc.
600 Delmar Avenue
Pointe Claire, Quebec
H9W 1E6
(514) 695-1220

Texasgulf Inc.
Suite 5000, Commercial Court West
Toronto, Ontario
M3C 2S2
(416) 869-1200

Van Waters and Rogers Ltd.
9800 Van Horne Way
Richmond, British Columbia
V6X 1W5
(604) 273-1441

3.4 Major Transportation Routes

Current Canadian production of potash (potassium chloride) is located in Saskatchewan (one plant is located in New Brunswick); the largest production plant is located in Esterhazy (24 percent of total production). Ninety-four percent of the product is exported. A major Canadian market area for potash is in Ontario. The product is shipped either by rail tank car or by truck. Most potash is shipped by rail to Vancouver for export; some potash is exported by truck to the United States.

3.5 Production Levels (Corpus 1984)

Company, Plant Location	Nameplate Capacity* kilotonnes/yr (1983)
Central Canada Potash (Noranda), Colonsay, Sask.	817
Cominco, Vade, Sask.	653
International Minerals and Chemical, Esterhazy, Sask.	2196
Kalium Chemicals (PPG Industries), Belle Plaine, Sask.	1035
Kidd Creek Mines, Allan, Sask.	956
Potash Co. of America (Ideal Basic), Lake Patience, Sask.	600
Potash Co. of America, Sussex, N.B.	380
Potash Corp. of Saskatchewan, Cory, Sask.	830
Potash Corp. of Saskatchewan, Lanigan, Sask.	692
Potash corp. of Saskatchewan, Rocanville, Sask.	1160
TOTAL	9319

Company, Plant Location	Nameplate Capacity* kilotonnes/yr (1983)
Domestic Production (1983)	6030
Imports (1983)	1
TOTAL SUPPLY	6031

* All values on K_2O basis - e.g. 0.63 x wt. of potassium chloride

3.6 Manufacture of Potash (FKC 1975; PCS 1982; Kirk-Othmer 1982)

3.6.1 General. Sylvinite ore is mined and crushed, and a brine is made. The brines are refined by successive flotations or crystallizations.

3.6.2 Manufacturing Processes.

3.6.2.1 Crystallization. Ore is dissolved in saturated potassium chloride/sodium chloride brine. At elevated temperatures, KCl is more soluble than NaCl; thus, the latter precipitates and is removed from the solution by filtering. The solution is then cooled to crystallize potassium chloride. The KCl crystals are then filtered and dried. The remaining brine is recycled.

3.6.2.2 Flotation. Ore is finely milled (for Saskatchewan ore, to a 9 mm screen; most others use a 2.3 mm screen) and "pulped" or slurried with brine. Clay is removed in a desliming process. The resulting slurry is first treated with dispersants (starches, carboxymethyl cellulose, polyacrylamides, etc.) to deactivate the remaining clay particles. The slurry is then treated with flotation agents (primary amines: palmetyl-, stearyl-, and oleylamines) and sometimes methyl isobutyl carbinol (MIBC) to supplement natural frothing agents. Amine-coated KCl grains float to the top with a small amount of fine NaCl grains. This froth is transferred to a second flotation cell (cleaner cell) for a final separation. Froth from the process is de-brined by centrifuge and dried. The resulting crystals are then sized.

3.7 Major Uses in Canada (Corpus 1984)

Potash is used in the production of NPK fertilizers, potassium sulphate, and caustic potash. It is also used in direct soil application and drilling muds. In 1983, 94 percent of domestic production was exported and 5 percent was used in the production of fertilizers.

3.8 Major Buyers in Canada (Corpus 1984)

Agricultural Chemicals, London, Ont.
Baroid of Canada, Calgary, Alta.
Bradford Fertilizer, Bradford, Ont.
C-I-L, Cornwall, Ingersoll, Chatham, Ont.
Co-opératives Fédérées du Québec, Montreal, Que.
Cyanamid Canada, Montreal, Que.
Manchester Products, Cambridge, Ont.
Milchem Canada, Calgary, Alta.
Nitrochem, Maitland, Ont.
Ontario Plant Food, Delhi, Ont.
Shamrock Chemicals, London, Ont.
Swift Canadian, Toronto, Ont.
United Co-operatives of Ontario, Mississauga, Ont.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

4.1.1 Bulk Shipment. A large percentage of potash is shipped by covered hopper car (rail), examples of which are depicted in Figure 3. Specifications for these rail cars are described in Table 2. Some potash is also hauled by truck.

4.1.2 Packaging. In addition to bulk shipment, potassium chloride is also transported in drums, bags and boxes. Drums fabricated from a variety of construction materials are permitted. Table 3 lists drum types and descriptions (TDGC 1980).

The following packaging systems are also used:

- Metal, wooden or fibreboard box with inner container fabricated from glass, metal, plastic or fibre.
- Fibreboard box with inner paper bag.
- Paper bag filled to weight with product and closed for shipment.

4.2 Specifications and Materials for Solution Handling

The materials of construction refer to those generally used in potassium chloride solution service. It is recognized that other materials may be used for particular applications, as indicated in Table 4. The components of a typical off-loading system that will be discussed include pipes and fittings, flexible connections, valves, gaskets, pumps and storage tanks. For off-loading potassium chloride bulk solids, chutes and hoppers, etc., can be made of ordinary steel plate.

Schedule 40 stainless steel rubber-lined pipes and fittings are recommended for solutions at normal operating temperature (PCS 1982).

Cast iron or cast steel diaphragm valves with polypropylene resin liner will serve adequately for all concentrations at almost all temperatures (DPLV 1972). Polypropylene can be used as a gasket material (DCRG 1978).

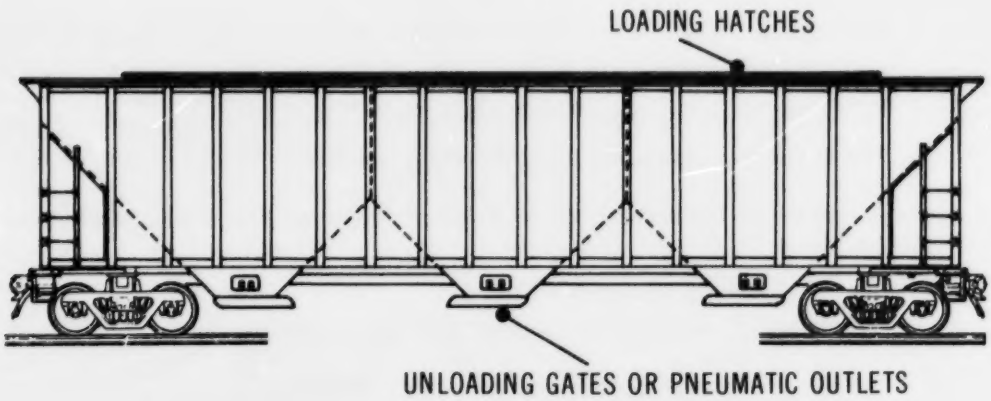
A single-suction centrifugal pump with stainless steel shaft and a cast stainless steel casing and impeller is recommended for pumping (HIS 1969). The material selected, however, must be chosen with concentration and temperature in mind. Back vanes on the impeller, an extra long stuffing box with a flowing water seal, and polypropylene backing will help reduce leakage. The pump and motor should be directly connected but not close coupled.

FIGURE 3

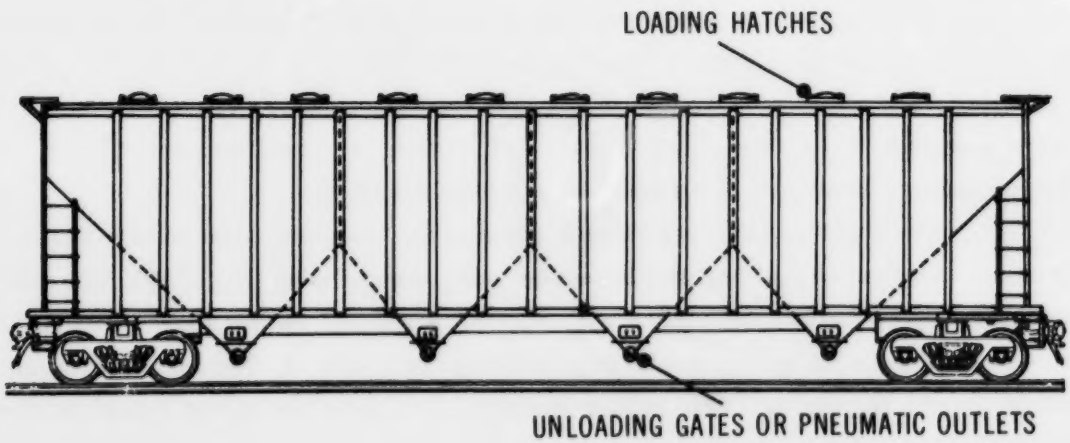
POTASSIUM CHLORIDE (potash)

COVERED HOPPER CARS - AAR CLASS LO

(Reference - CLC 1974; AAR 1983)



Typical 3 - Compartment Hopper Car



Typical 4 - Compartment Hopper Car

TABLE 2 TYPICAL RAILWAY HOPPER CAR SPECIFICATIONS - AAR Class LO (CLC 1974)

Description	Hopper Car Size (cu. ft.) 5800		4700	
Overall				
Nominal capacity	164 m^3	(5800 cu. ft.)	133 m^3	(4700 cu. ft.)
Weight capacity	86 000 kg	(190 000 lb.)	89 000 kg	(196 000 lb.)
Car weight - empty	45 000 kg	(100 000 lb.)	45 000 kg	(100 000 lb.)
Car weight - max.	119 000 kg	(263 000 lb.)	119 000 kg	(263 000 lb.)
Hoppers/Compartments				
Number	4		3	
Material	Steel			
Inside length (typical)	410 cm	(160 in.)	460 cm	(180 in.)
Inside width (typical)	300 cm	(118 in.)	300 cm	(118 in.)
Spacing between outlets	4 m	(13 ft.)	5 m	(15 ft.)
Slope angle	40-45°		40-45°	
Approximate Dimensions				
Coupled length	21 m	(68 ft.)	18 m	(60 ft.)
Length over strikers	20 m	(65 ft.)	17 m	(57 ft.)
Length of truck centers	16 m	(54 ft.)	14 m	(46 ft.)
Clearance height	5 m	(15 ft.)	5 m	(15 ft.)
Height to top of running board	5 m	(15 ft.)	4 m	(14 ft.)
Overall width	3.2 m	(123 in.)	3.2 m	(126 in.)
Inside length	19 m	(63 ft.)	17 m	(55 ft.)

Loading/Unloading Fixtures

Loading Hatches: Cars typically equipped with 4 to 12 loading hatches. Typical dimensions of these are 36-61 cm (14-24 in.) in diameter or square dimensions.

Unloading Fixtures: Equipped with unloading gates at bottom of 36-61 cm (14-24 in.) square and/or pneumatic unloading connections 10-20 cm (4-8 in.) in diameter.

TABLE 3 DRUMS

Type of Drum	Designation	Description	Figure No. (if any)
Steel	1A1	Nonremovable head, reusable	4
	1A1A	1A1 with reinforced chime	4
	1A1B	1A1 with welded closure flange	4
	1A1C	1A1 with lead coating	4
	1A1D	1A1 with coating (other than lead)	4
	1A2	Removable head, reusable	4
	1A2A	1A2 with reinforced chime	4
	1A2B	1A2 with lead coating	4
	1A3	Nonremovable head, single use only	4
	1A4	Removable head, single use only	4
Monel*	TC5M		4
Aluminum	1B1	Nonremovable head	4
	1B2	Removable head	4
Plywood	1D2		
Fibreboard	1G1	Convolutely wound plies. Maximum capacity 250 L (55 gal.) Maximum net mass 400 kg (882 lb.)	
Plastic	1H1	Nonremovable head. Maximum capacity 250 L (55 gal.) Maximum net mass 400 kg (882 lb.)	
	1H2	Same as 1H1 except head removable	
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity 225 L (49 gal.)	
Plywood with inner plastic receptacles	6HD1	Outer plywood in shape of drum. Inner plastic receptacle. Maximum capacity 225 L (49 gal.)	
Fibreboard drums with inner plastic receptacles	6HG1	Outer containers of convolutely wound plies of fibreboard. Inner plastic in shape of drum. Maximum capacity 225 L (49 gal.)	

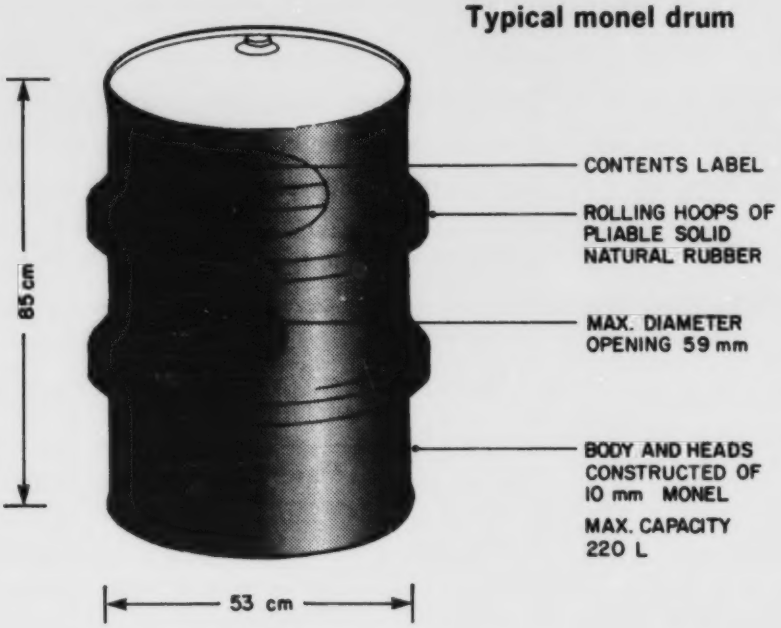
* See Section 4.3 of this report.

FIGURE 4

POTASSIUM CHLORIDE (potash)

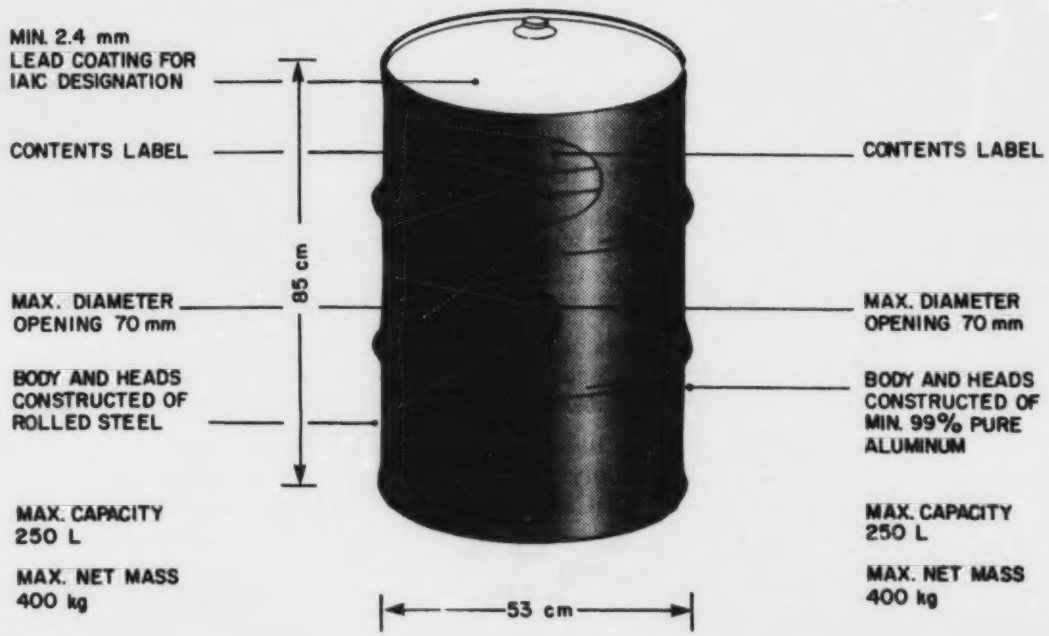
TYPICAL DRUM CONTAINERS

Typical monel drum


85 cm
53 cm
CONTENTS LABEL
ROLLING HOOPS OF PLIABLE SOLID NATURAL RUBBER
MAX. DIAMETER OPENING 59 mm
BODY AND HEADS CONSTRUCTED OF 10 mm MONEL
MAX. CAPACITY 220 L

Typical steel drum

Typical aluminum drum


MIN. 2.4 mm LEAD COATING FOR IAIC DESIGNATION
CONTENTS LABEL
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF ROLLED STEEL
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg
85 cm
53 cm
CONTENTS LABEL
MAX. DIAMETER OPENING 70 mm
BODY AND HEADS CONSTRUCTED OF MIN. 99% PURE ALUMINUM
MAX. CAPACITY 250 L
MAX. NET MASS 400 kg

Welded carbon steel storage tanks with rubber lining or stainless steel cladding will minimize corrosion. At elevated temperatures, a hypalon liner inside the tank is recommended (GF).

4.3 Compatibility with Materials of Construction

The compatibility of potassium chloride with materials of construction is indicated in Table 4. The unbracketed abbreviations are described in Table 5. The rating system for this report is briefly described below.

Recommended: This material will perform satisfactorily in the given application.

Conditional: Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.

Not Recommended: Material will be severely affected in this application and should not be used.

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

	Chemical		Material of Construction		
Application	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings	All	49	PE (DPPED 1967)		
		52	PVDC (DCRG 1978)		
		60	PVC I PVC II (DPPED 1967)		
		71	ABS (DPPED 1967)		
		93	PP (DCRG 1978)		
		< 93	Rubber-lined CS FRP, FP (Kerr-McGee Bulletin)		
		> 93	Monel 400 Incoloy 825 Carpenter 20 C6-3 Titanium		
		121	Chlorinated Polyether (DCRG 1978)		
		135	PVDF (DCRG 1978)		

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical		Material of Construction		
	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
1. Pipes and Fittings (Cont'd)		To operating limit of material	PVC I ABS PE (MWPP 1978)		
		<71	Rubber-lined CS		
		<71	FRP		
		>94	Titanium Monel		
2. Valves	All	Boiling	Alloy 20 (JSSV 1979)	SS 316 (JSSV 1979)	
3. Pumps	All	80	GRP with FPM A "0" Ring		
		Most	Durimet 20 (Kerr-McGee Bulletin)		
	Aqueous Solution	<80	Alloy "20" All Bronze SS 304, SS 316 Monel (HIS 1969)		
4. Storage			SS, CS		
	All	<93	Rubber-lined CS FRP, EP (Kerr-McGee Bulletin)		
		>93	Rubber-lined CS plus brick (Kerr-McGee Bulletin)		
5. Others	1 and 5%	20	SS 302, SS 304, SS 316, SS 430 (ASS)	SS 410 (ASS)	
		Boiling	SS 302, SS 304, SS 316 (ASS)		
	Saturated	20	SS 302, SS 304, SS 316 (ASS)	SS 410, SS 430 (ASS)	
	Saturated (Aqueous)	60	uPVC, PE, PP, POM, NR, NBR, IIR, EPDM, CR, FPM, CSM (GF)		

TABLE 4 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION (Cont'd)

Application	Chemical		Material of Construction		
	Conc.	Temp. (°C)	Recommended	Conditional	Not Recommended
5. Others (Cont'd)		100	NBR, IIR, EPDM, CR, FPM, CSM (GF)	PP (GF)	uPVC, PE, POM NR (GF)
		60	PVC (TPS 1978)		
		82	PP (TPS 1978)		
		85	CPVC (TPS 1978)		
		121	PVDF (TPS 1978) SBR, Si (GPP)		
	10-20%	24 to 100	Glass (CDS 1967)		
	30%	100	Glass (CDS 1967)		
	100%	24 to 100	Glass (CDS 1967)		
	10 or 30%	24			Concrete (CDS 1967)
	10%	24	Wood (CDS 1967)		

TABLE 5 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Alloy 20
	Aluminum
	Bronze
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene)
CS	Carbon Steel
CSM	Chlorosulphonated Polyethylene (Hypalon)

TABLE 5 MATERIALS OF CONSTRUCTION (Cont'd)

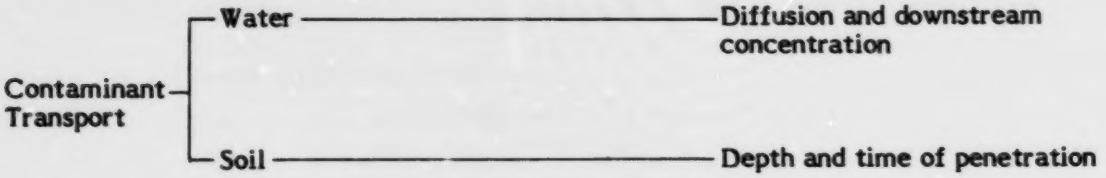
Abbreviation	Material of Construction
EP	Epoxy Plastic
EPDM	Ethylene Propylene Rubber
FRP	Fibre Reinforced Plastic
FPM	Fluorine Rubber (Viton)
	Glass
GRP	Glass Reinforced Vinyl Ester
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber
NR	Natural Rubber
	Nickel
	Nickel-Copper Alloy (Monel)
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PVC (Followed by grade, if any)	Polyvinyl Chloride
PVCD	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
Si	Silicon
SBR	Styrene/Butadiene (GR-5) Rubber
SS (Followed by grade)	Stainless Steel
uPVC	Unplasticized Polyvinyl Chloride
	Wood (Spruce, Fir)

5 CONTAMINANT TRANSPORT

5.1 General Summary

Potassium chloride (potash) is normally transported in bulk, as a solid, in hopper-type bulk cars. When spilled in water, it will dissolve. If solid material is spilled on the soil, there would be minimal concern regarding possible water table contamination. However, if water were present in the area of the spill or if rainfall occurred after the spill, some of the material would dissolve and penetrate the soil. Transport of potassium chloride toward the water table may be an environmental concern.

Because potassium chloride is essentially nonvolatile, dispersion in air is not a problem. The following factors are considered for the transport of a spill in water and soil:



It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

5.2 Leak Nomograms

5.2.1 Introduction. Potassium chloride (potash) is normally transported in bulk as a solid and only very occasionally as an aqueous solution. In bulk form, potassium chloride is carried in railway cars or hopper type bulk cars. In aqueous form, it is transported in cylindrical unpressurized railway tank cars. Because it is so seldom shipped as a liquid, no leak nomograms have been prepared.

5.3 Dispersion in the Air

Because potassium chloride (potash) is nonvolatile in foreseeable spill circumstances, there is no significant potential for dispersion in air.

5.4 Behaviour in Water

5.4.1 Introduction. Potassium chloride is soluble in water. When spilled on a water surface, mixing takes place and the spill is diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence while in calm water mixing takes place by molecular diffusion.

To estimate pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The model employed is strictly applicable to neutrally buoyant liquids and solids that dissolve in water. As potassium chloride is denser than water, the maximum concentration would be expected near the bottom.

The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 (W/d <100) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

5.4.2 Nomograms. The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

Non-tidal Rivers

Figure 6:	time versus distance for a range of average stream velocities
Figure 7:	hydraulic radius versus channel width for a range of stream depths
Figure 8:	diffusion coefficient versus hydraulic radius for a range of average stream velocities
Figure 9:	alpha* versus diffusion coefficient for various time intervals
Figure 10:	alpha versus delta* for a range of spill sizes
Figure 11:	maximum concentration versus delta for a range of river cross-sectional areas

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* Alpha and delta are conversion factors only and are of no significance other than to facilitate calculation of downstream concentration.

Lakes or Still Water Bodies

Figure 12: volume versus radius for the hazard zone for a range of lake depths

Figure 13: average concentration versus volume for the hazard zone for a range of spill sizes

The flowchart in Figure 5 outlines the steps required to estimate the downstream concentration after a spill and identifies the nomograms to be used. These nomograms (Figures 6 through 13) are described in the following subsections.

5.4.2.1 Nomograms for non-tidal rivers.

Figure 6: Time versus distance. Figure 6 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average velocity (U), the time (t) to reach any point of interest, at some distance (X) downstream of the spill, can be readily obtained from Figure 6.

Figure 7: Hydraulic radius versus channel width. The model used to estimate downstream pollutant concentrations is based on an idealized rectangular channel of width (W) and depth (d). The hydraulic radius (r) for the channel is required in order to estimate the turbulent diffusion coefficient (E). The hydraulic radius (r) is defined as the stream cross-sectional area (A) divided by the wetted perimeter (P). Figure 7 is a nomogram for computation of the hydraulic radius (r) using the width and depth of the idealized river cross-section.

Figure 8: Diffusion coefficient versus hydraulic radius. Figure 8 permits calculation of the longitudinal diffusion coefficient (E), knowing the hydraulic radius (r) from Figure 7 and the average stream velocity (U).

Figure 9: Alpha versus diffusion coefficient. Figure 9 is used to estimate a conversion factor, alpha (α), which is a function of the diffusion coefficient (E) and the time (t) to reach the point of interest downstream of the spill.

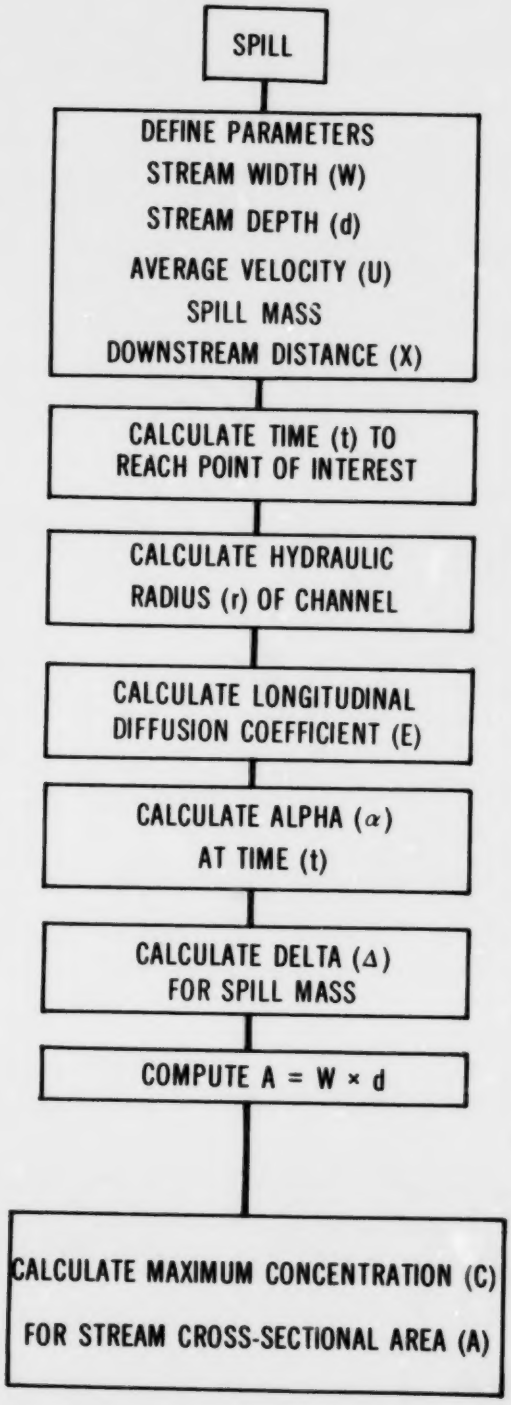
Figure 10: Alpha versus delta. A second conversion factor, delta (Δ), must be estimated from Figure 10 to allow determination of the pollutant concentration at the point of interest. Delta (Δ) is a function of alpha (α) and the spill size.

Figure 11: Maximum concentration versus delta. Figure 11 represents a final step for calculation of the maximum downstream pollutant concentration (C) at the point of interest. Using the factor delta (Δ) and knowing the stream cross-sectional area (A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 11 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

FIGURE 5

POTASSIUM CHLORIDE (potash)

FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS


SPILL
DEFINE PARAMETERS
STREAM WIDTH (W)
STREAM DEPTH (d)
AVERAGE VELOCITY (U)
SPILL MASS
DOWNSTREAM DISTANCE (X)
CALCULATE TIME (t) TO REACH POINT OF INTEREST
CALCULATE HYDRAULIC RADIUS (r) OF CHANNEL
CALCULATE LONGITUDINAL DIFFUSION COEFFICIENT (E)
CALCULATE ALPHA (α) AT TIME (t)
CALCULATE DELTA (Δ) FOR SPILL MASS
COMPUTE A = W × d
CALCULATE MAXIMUM CONCENTRATION (C) FOR STREAM CROSS-SECTIONAL AREA (A)

Step 1: Observed or Estimated

W = _____ m

d = _____ m

U = _____ m/s

MASS = _____ tonnes

X = _____ m

Step 2: Use Figure 6

t = _____ minutes

Step 3: Use Figure 7

r = _____ m

Step 4: Use Figure 8

E = _____ m^2/s

Step 5: Use Figure 9

α = _____

Step 6: Use Figure 10

Δ = _____

Step 7: Compute stream cross-sectional Area (A)

A = W × d _____ m^2

Step 8: Use Figure 11

C = _____ ppm

FIGURE 6

POTASSIUM CHLORIDE (potash)

TIME vs DISTANCE

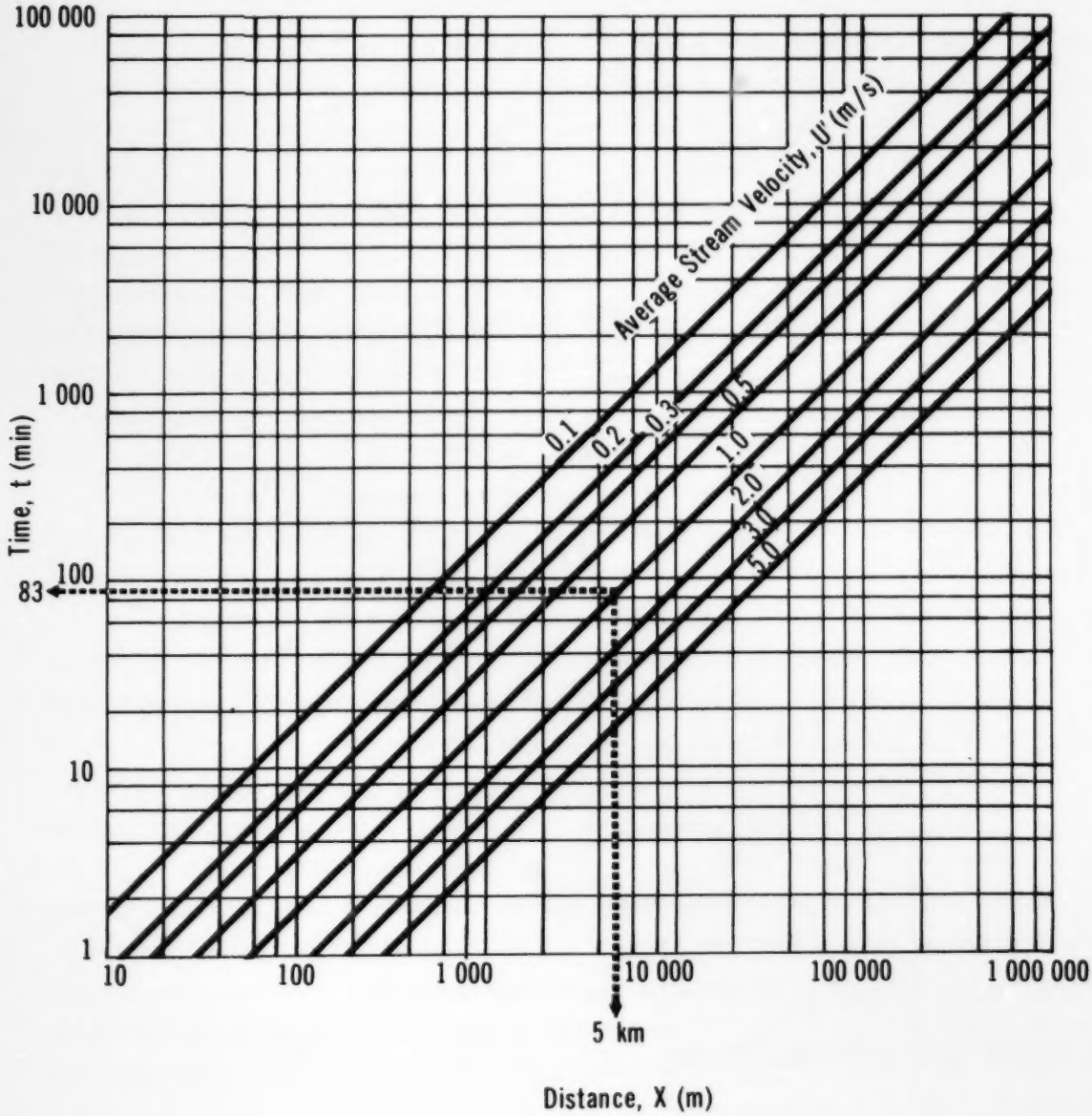


FIGURE 7

POTASSIUM CHLORIDE (potash)

HYDRAULIC RADIUS VS CHANNEL WIDTH

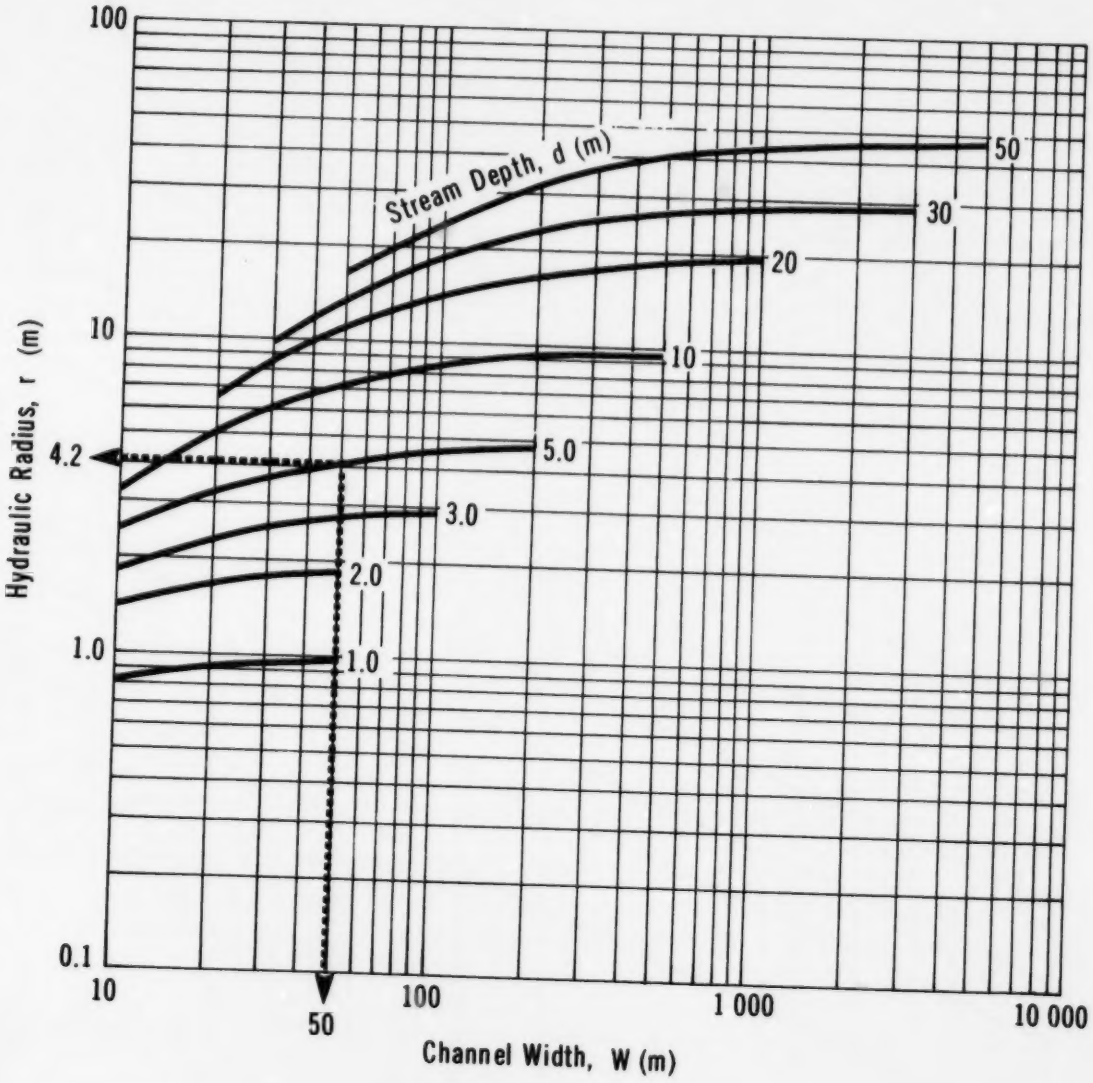


FIGURE 8

POTASSIUM CHLORIDE (potash)

DIFFUSION COEFFICIENT VS HYDRAULIC RADIUS

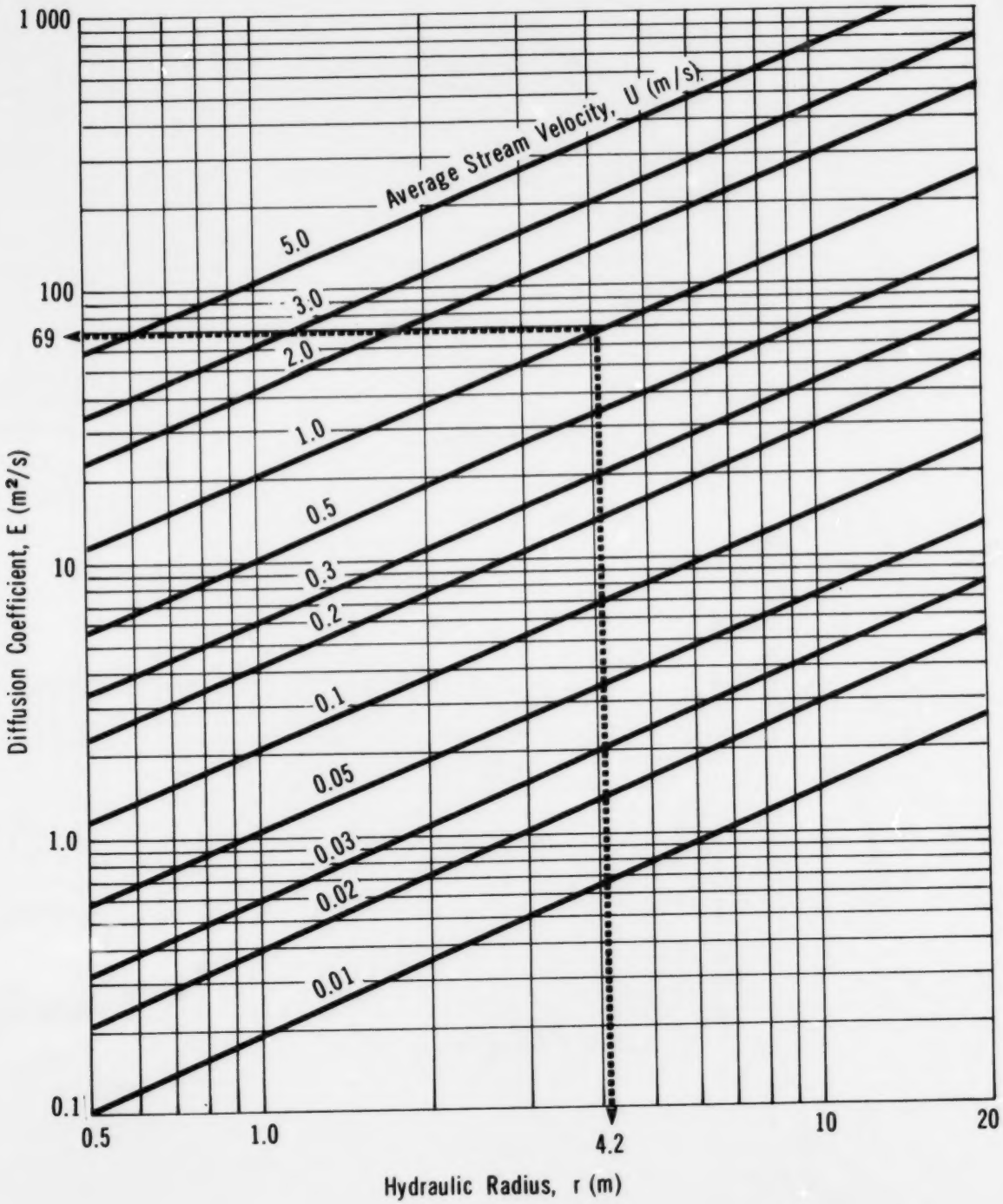


FIGURE 9

POTASSIUM CHLORIDE (potash)

ALPHA vs DIFFUSION COEFFICIENT

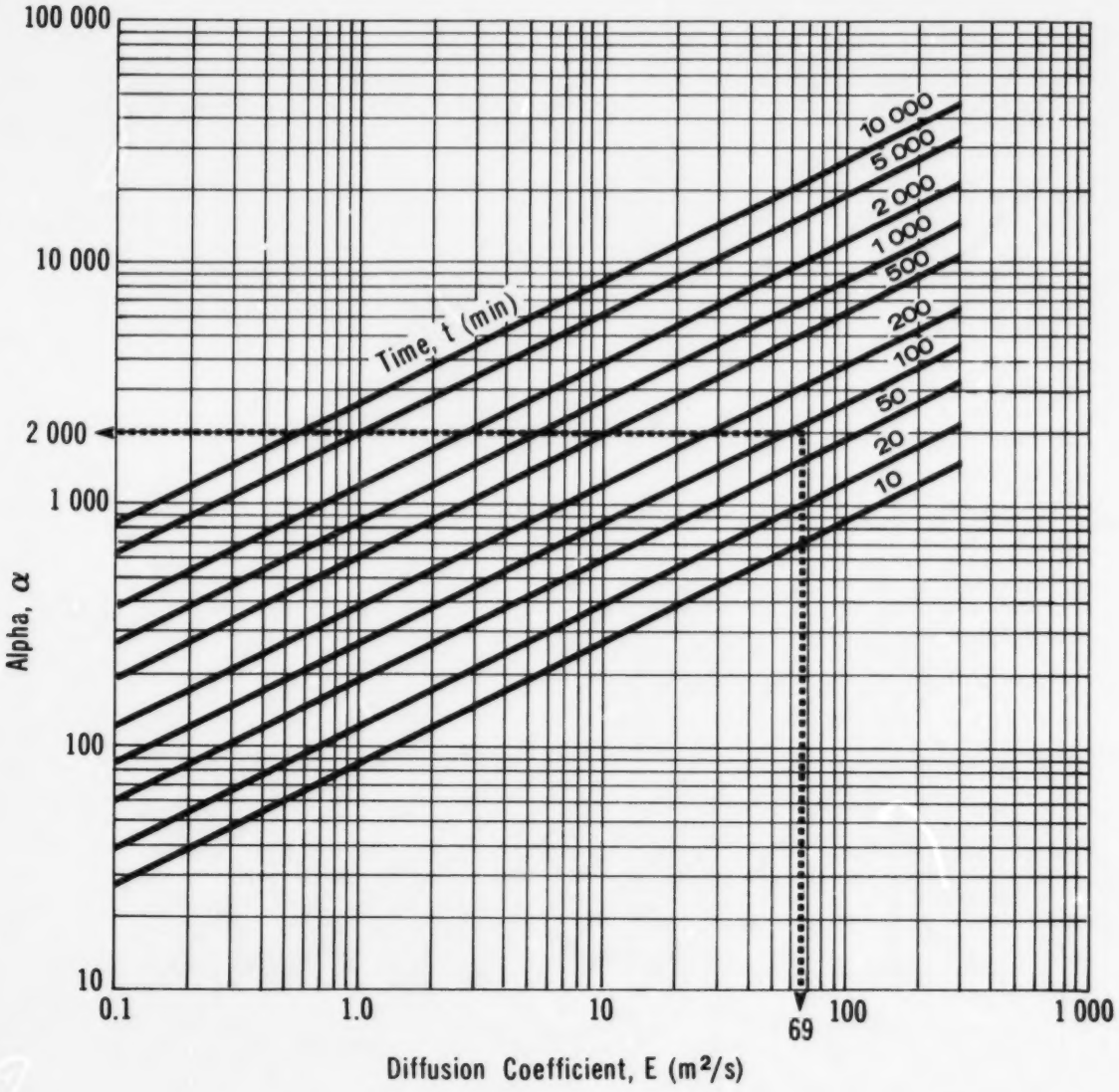


FIGURE 10

POTASSIUM CHLORIDE (potash)

ALPHA vs DELTA

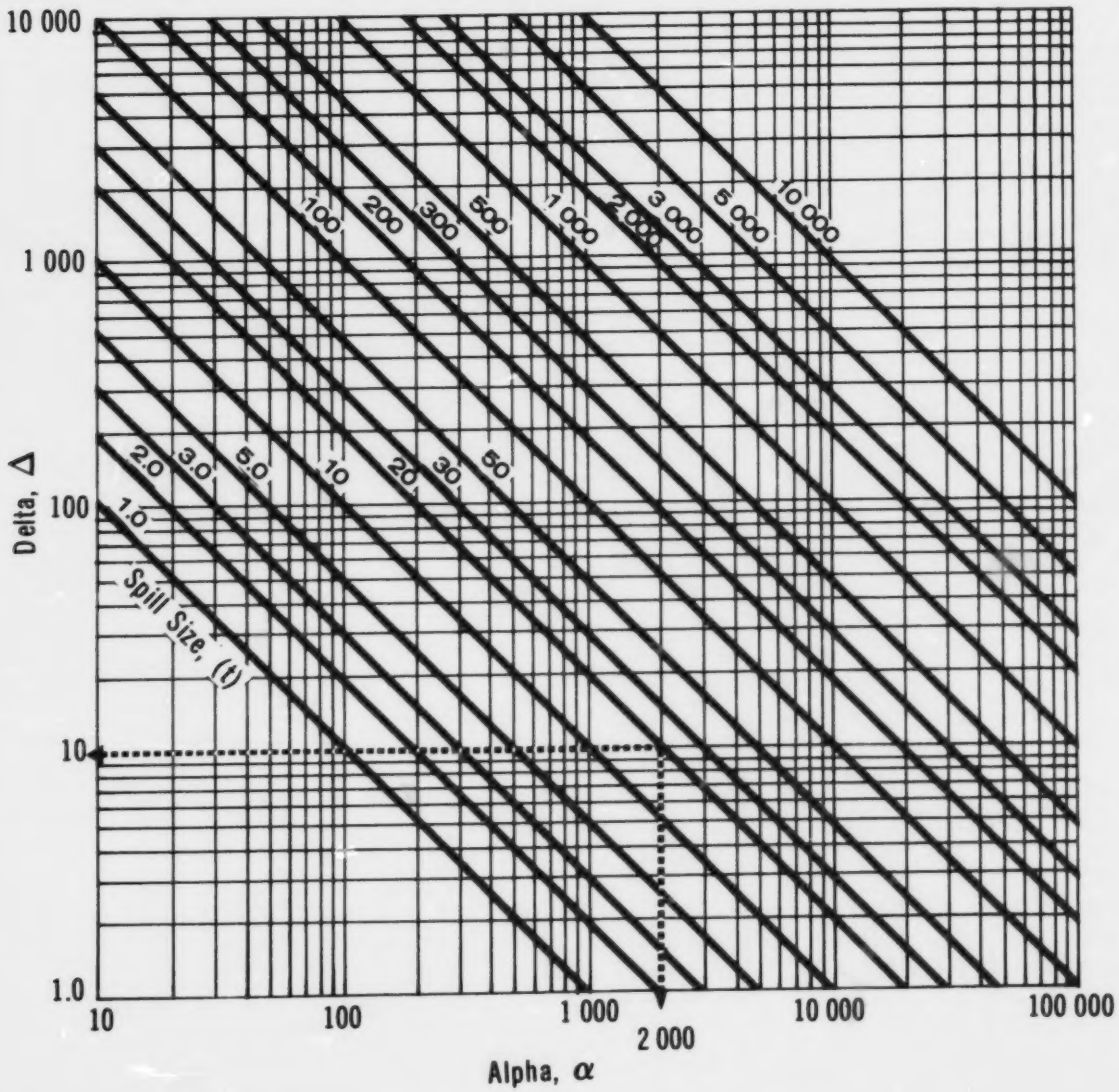
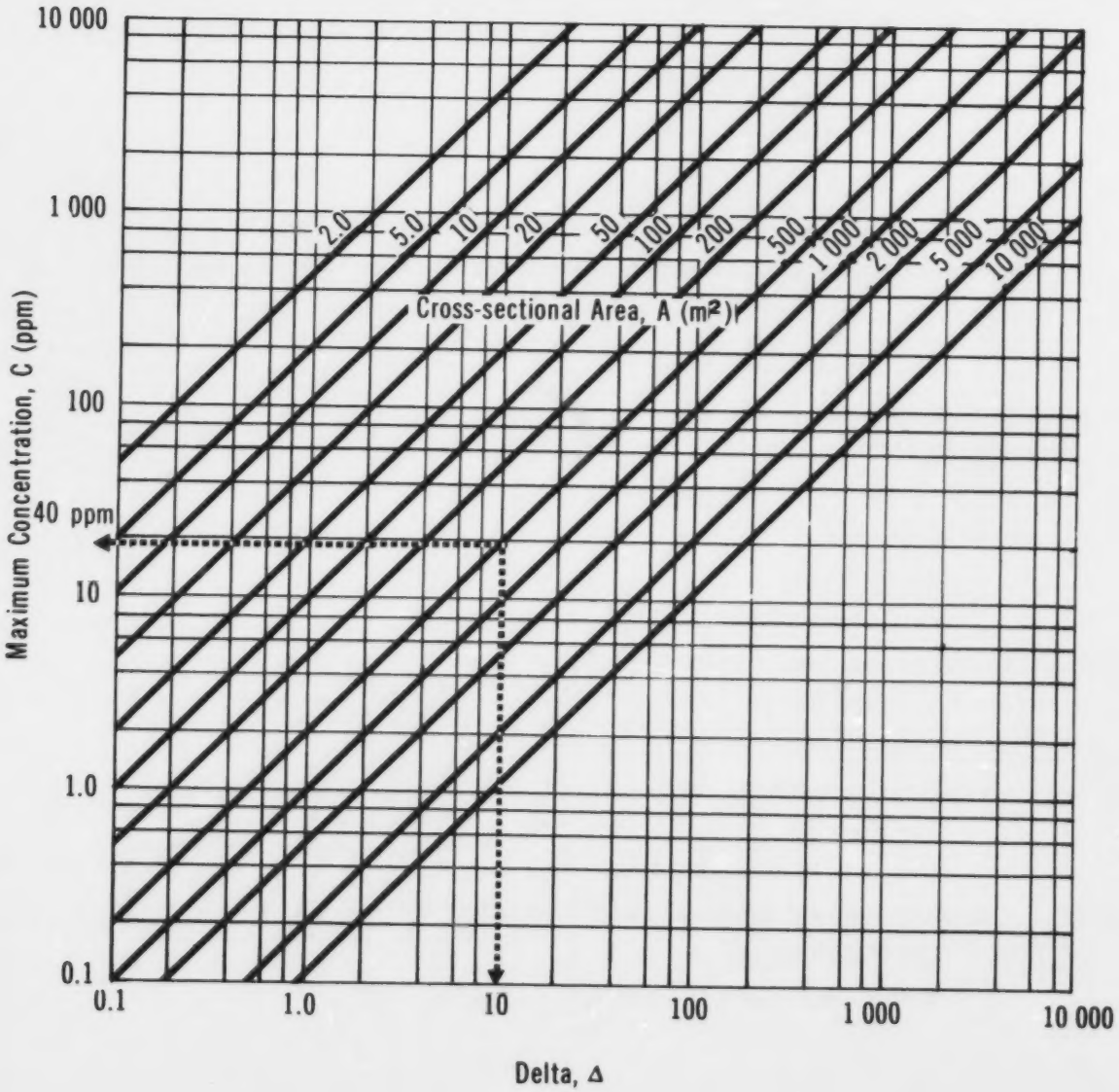


FIGURE 11

POTASSIUM CHLORIDE (potash)

MAXIMUM CONCENTRATION vs DELTA



5.4.2.2 Nomograms for lakes or still water bodies.

Figure 12: Volume versus radius. The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius (r) and length (d), equivalent to the depth of the lake at the point of spill. The volume of water in the cylinder can be obtained from Figure 12. The radius (r) represents the distance from the spill to the point of interest.

Figure 13: Average concentration versus volume. For a known volume of water (within the idealized cylinder of radius (r) and length (d)), the average concentration of pollutant (C) can be obtained from Figure 13 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

5.4.3 Sample Calculations.

5.4.3.1 Pollutant concentration in non-tidal rivers. A 20 tonne spill of potassium chloride (potash) has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

Solution

Step 1: Define parameters

- W = 50 m
- d = 5 m
- U = 1 m/s
- X = 5000 m
- spill mass = 20 tonnes of potassium chloride

Step 2: Calculate the time to reach the point of interest

- Use Figure 6
- With X = 5000 m and U = 1 m/s, t = 83 min

Step 3: Calculate the hydraulic radius (r)

- Use Figure 7
- With W = 50 m and d = 5 m, r = 4.2 m

Step 4: Calculate the longitudinal diffusion coefficient (E)

- Use Figure 8
- With r = 4.2 m and U = 1 m/s, E = 69 m^2/s

FIGURE 12

POTASSIUM CHLORIDE (potash)

VOLUME vs RADIUS

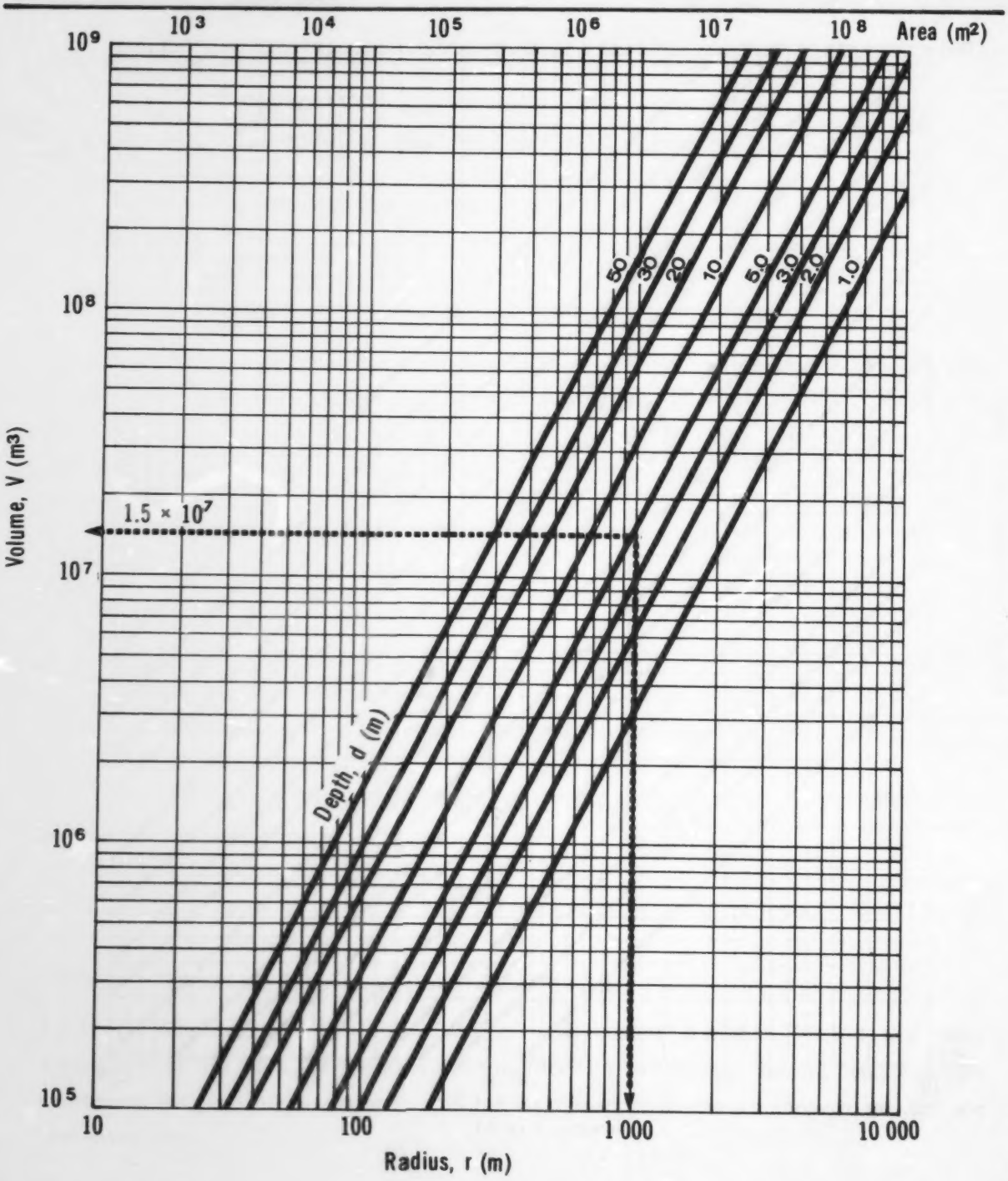
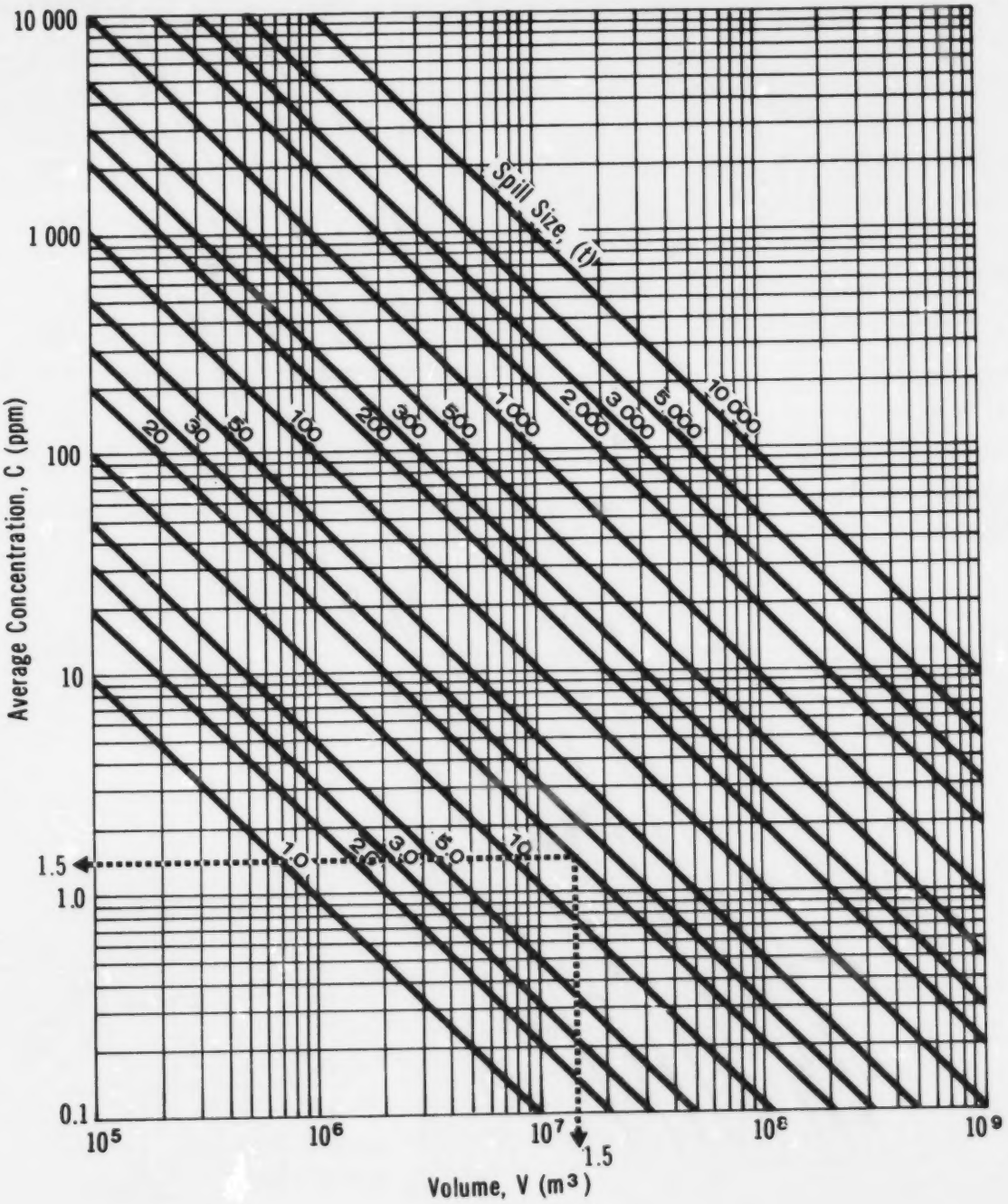


FIGURE 13

POTASSIUM CHLORIDE (potash)

AVERAGE CONCENTRATION vs VOLUME



Step 5: Calculate alpha (α)

- Use Figure 9
- With E = 69 m^2/s and t = 83 min, α = 2000

Step 6: Calculate delta (Δ)

- Use Figure 10
- With alpha (α) = 2000 and spill mass = 20 tonnes, delta (Δ) = 10

Step 7: Compute the stream cross-sectional area (A)

- A = W x d = 50 x 5 = 250 m^2

Step 8: Calculate the maximum concentration (C) at the point of interest

- Use Figure 11
- With Δ = 10 and A = 250 m^2, C = 40 ppm

5.4.3.2 Average pollutant concentration in lakes or still water bodies. A 20 tonne spill of potassium chloride (potash) has occurred in a lake. The point of interest is located on the shore approximately 1000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

Solution

Step 1: Define parameters

- d = 5 m
- r = 1000 m
- spill mass = 20 tonnes

Step 2: Determine the volume of water available for dilution

- Use Figure 12
- With r = 1000 m, d = 5 m, the volume is approximately 1.5 x 10^7 m^3

Step 3: Determine the average concentration

- Use Figure 13
- With V = 1.5 x 10^7 m^3 and spill mass = 20 tonnes, the average concentration is 1.5 ppm

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Mechanisms. The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of potash onto soil and its transport downward through the soil are presented here.

Potash is conveyed primarily as a solid. Consequently, when spilled, only a limited groundwater contamination hazard exists if the soil is dry and if no precipitation falls prior to cleanup. However, if precipitation or other forms of moisture are present, groundwater contamination can be expected.

Since potash is very soluble (34.4 g/100 g at 20°C), strong solutions can infiltrate the soil. Some interaction between potash and the soil, probably in the form of ion exchange, will occur. However, much of the salt together with exchanged ions will migrate downward through the soil. The potassium ion itself is relatively immobile in clay or silt soils; concentrations will migrate only 1 to 2 cm per year depending on the soil and moisture (Redmann 1978). However, in the case of excess water, this rate will dramatically increase.

If the soil surface is saturated with moisture at the time of the spill, as might be the case after a rainfall, the spilled contaminant dissolved in the precipitation will run off. For this work, the soils have been assumed to be at field capacity. This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents "worst case" analysis.

Upon reaching the groundwater table, the contaminant will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with diffusion and dispersion serving to reduce the concentration somewhat. This is shown schematically in Figure 14.

5.5.2 Equations Describing Dissolved Potash Movement into Soil. The equations and assumptions used to describe contaminant movement in solution downward through the unsaturated soil zone toward the groundwater table have been described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Dissolved Potash in Soil. The saturated hydraulic conductivity (K_o), in m/s, is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

where: k = intrinsic permeability of the soil (m^2)

ρ = mass density of the fluid (kg/m^3)

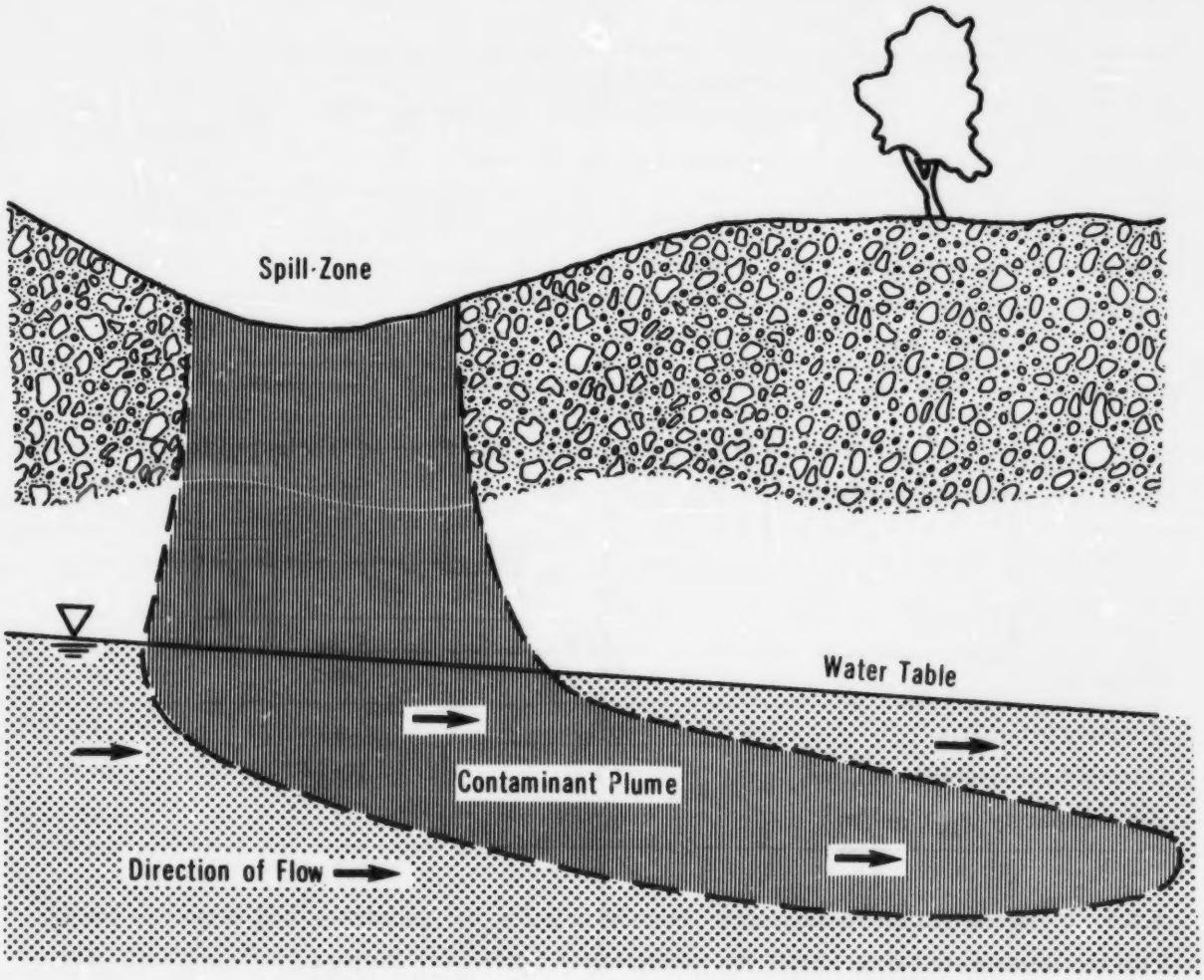
μ = absolute viscosity of the fluid ($Pa \cdot s$)

g = acceleration due to gravity = 9.81 m/s^2

FIGURE 14

POTASSIUM CHLORIDE (potash)

SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity (n) = 0.35

–Intrinsic Permeability (k) = 10^{-9} m^2

–Field Capacity (θ_{fc}) = 0.075

The fluids involved are 20 percent potash by weight as an example of a strong solution, and water. The water calculations represent the extreme as the solution is diluted.

Property	Potash (20% by Wt.)		Water
	20°C	4°C	20°C
Mass density (ρ), kg/m^3	1133	1137	998
Absolute viscosity (μ), Pa•s	1.9 x 10^{-3}	2.4 x 10^{-3}	1.0 x 10^{-3}
Saturated hydraulic conductivity (K_o), m/s	(0.58 x 10^7)k	(0.46 x 10^7)k	(0.98 x 10^7)k

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

Property	Soil Type		
	Coarse Sand	Silty Sand	Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45

5.5.5 Penetration Nomograms. Nomograms for the penetration of dissolved potash into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time (t_p) plotted against depth of penetration (B). Because of the methods and asumptions used, the penetration depth should be considered as a maximum depth in time t_p.

A flowchart for the use of the nomograms is presented in Figure 15. The nomograms are presented as Figures 16, 17 and 18. The water line on the nomograms represents the maximum penetration of water at 20°C in time t_p. It is a limiting condition as the potash becomes more diluted.

FIGURE 15

POTASSIUM CHLORIDE (potash)

FLOWCHART FOR NOMOGRAM USE

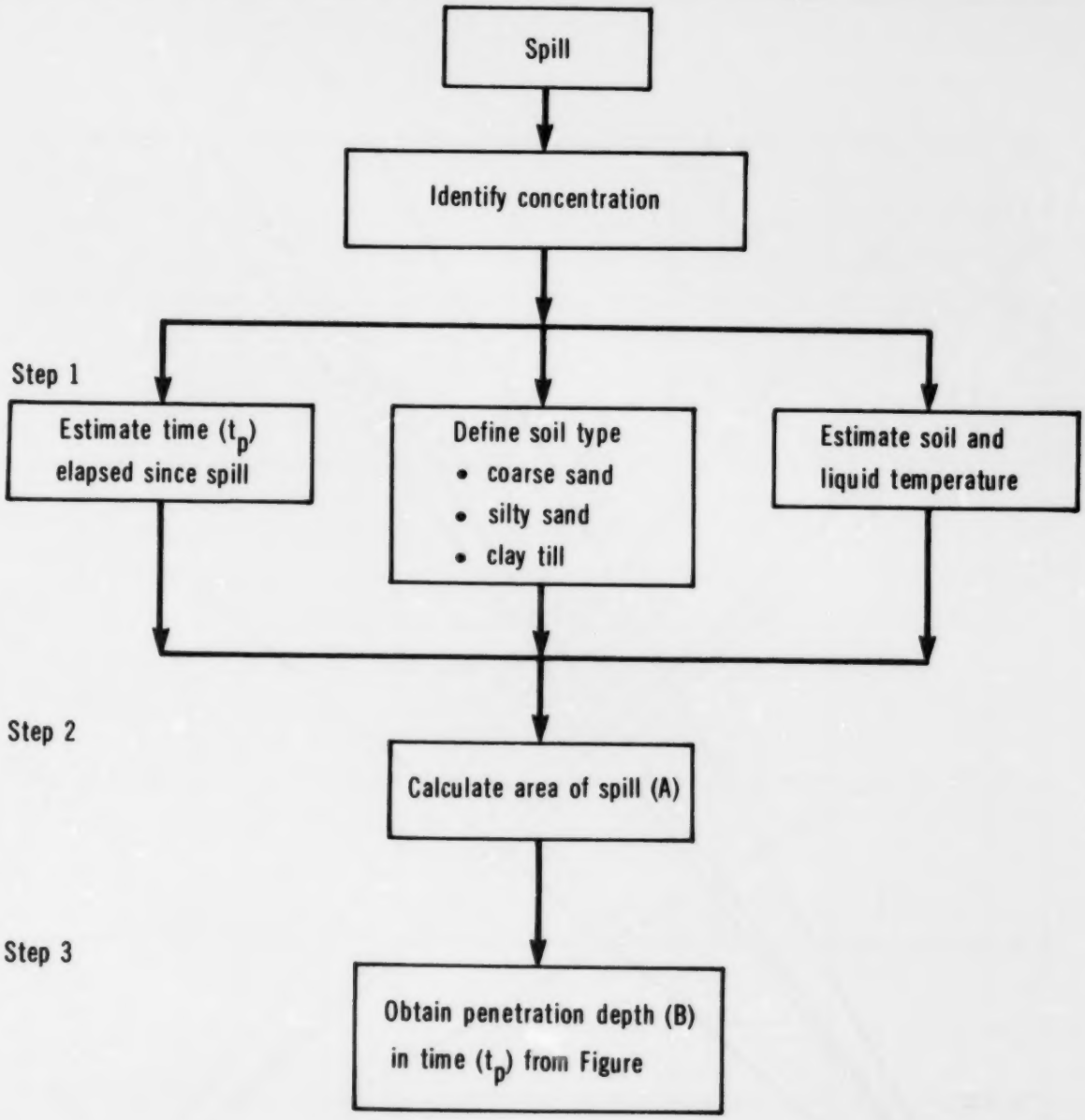


FIGURE 16

POTASSIUM CHLORIDE (potash)

PENETRATION IN COARSE SAND

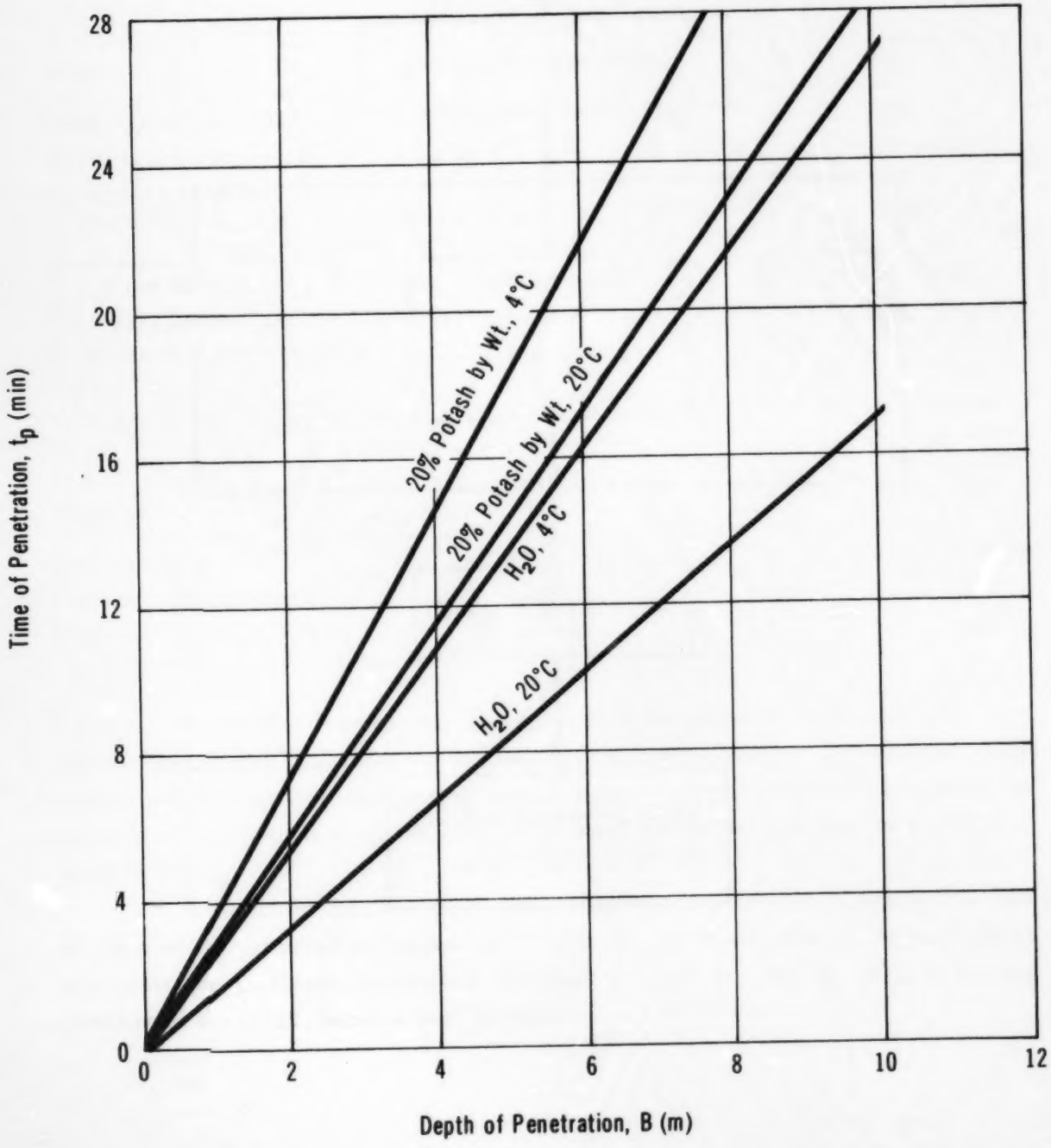


FIGURE 17

POTASSIUM CHLORIDE (potash)

PENETRATION IN SILTY SAND

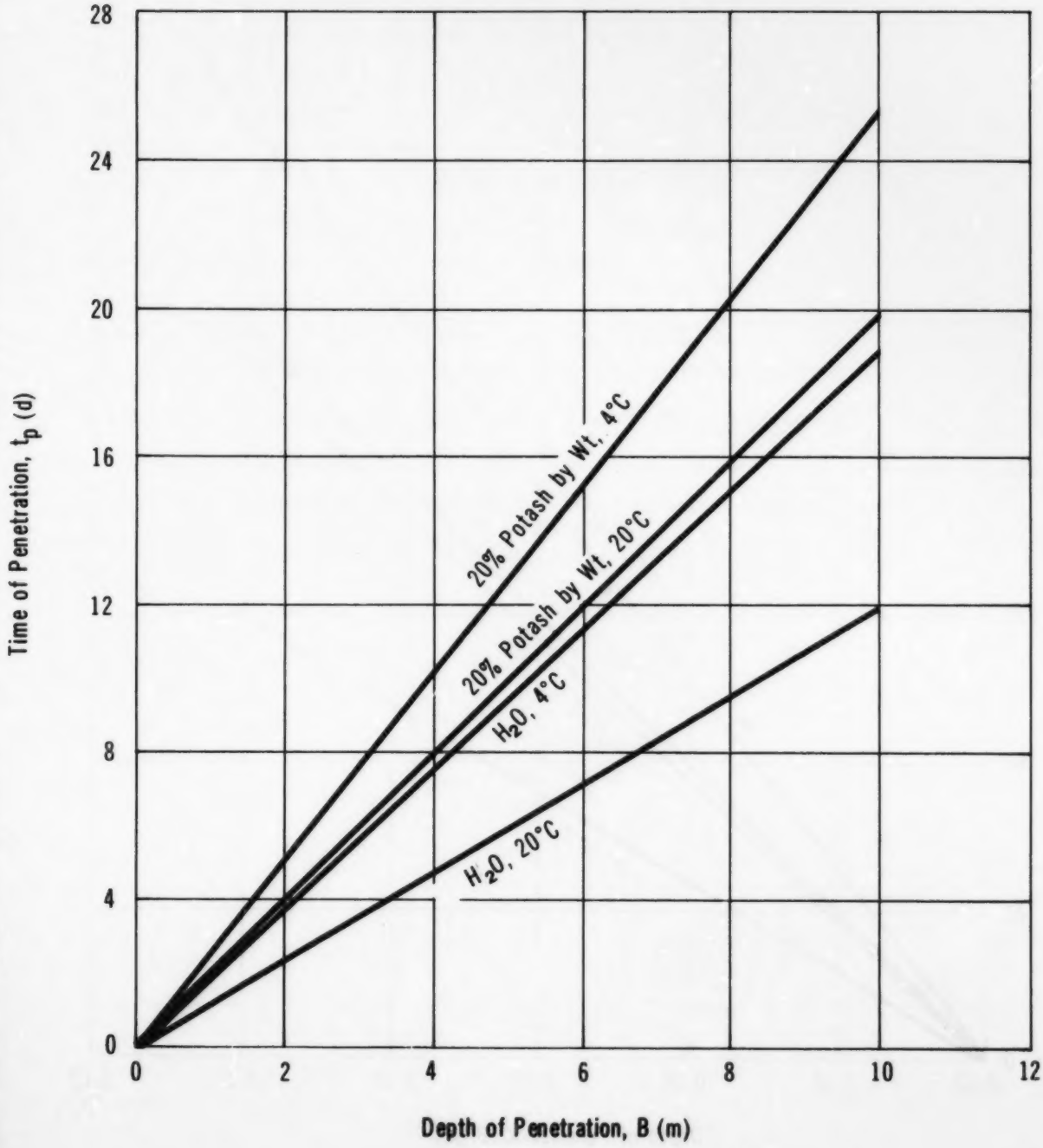
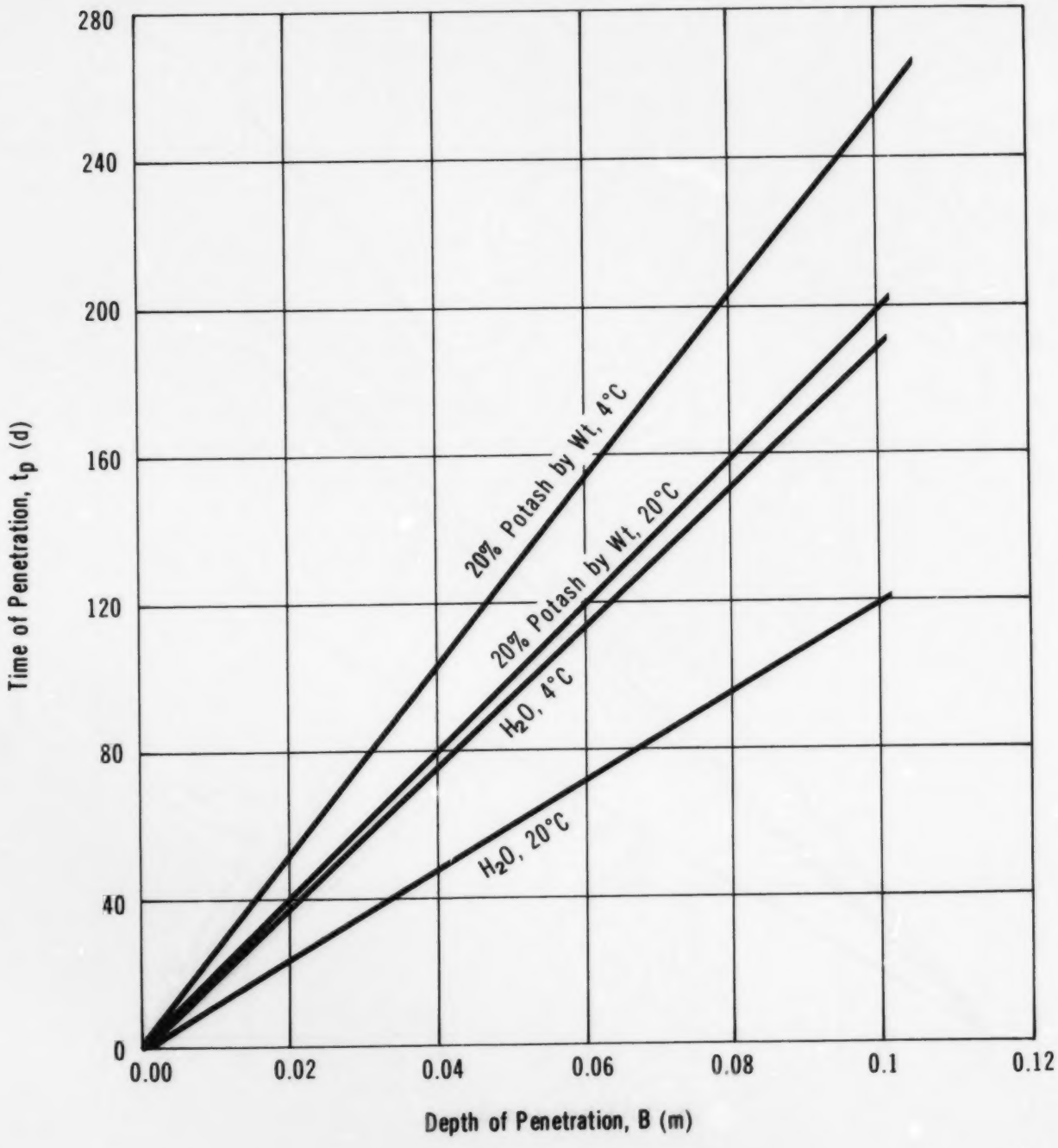


FIGURE 18

POTASSIUM CHLORIDE (potash)

PENETRATION IN CLAY TILL



5.5.6 Sample Calculation. A 20 tonne spill of potash has occurred on silty sand. The temperature is 20°C; the spill radius is 8.6 m. During cleanup, it begins to rain. Calculate the depth of penetration 4 days after the rain has begun.

Solution

Step 1: Define parameters

- Mass spilled = 20 000 kg (20 tonnes)
- T = 20°C
- r = 8.6 m
- Soil = silty sand
- Groundwater table depth (d) = 13 m
- Time since spill (t_p) = 4 days

Step 2: Calculate the area of spill

- $A = \pi r^2 = 232\ m^2$

Step 3: Estimate the depth of penetration (B) at time (t_p)

- For silty sand and t_p = 4 days, the penetration range is

20% Potash by Wt.	Dilute (Water, worst case)
2.0 m	3.5 m

- Groundwater table has not been reached at this point

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. No limits have been set for potassium chloride in water.

6.1.2 Air. Saskatchewan limits airborne potash emissions to 0.15 mg/cm^2 over a 30-day period (Sask. APCA 1978).

6.2 Aquatic Toxicity

6.2.1 U.S. Toxicity Rating. No TL_m96 has been assigned (RTECS 1979).

6.2.2 Measured Toxicities.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Kill Data					
74.6	4.5 to 15	Goldfish	killed	distilled	WQC 1963
373	12 to 29	Minnows (*Notropis blennis*)	killed	room temperature	WQC 1963
751		Pickerel	killed	Lake Erie	WQC 1963
1360	72	Perch	killed	well	WQC 1963
2300	24	Small freshwater fish	killed		WQC 1963
10 368	t.n.s.	Whitefish fry	killed	Lake Erie	WQC 1963
15 600	1.2	Goldfish	killed	-	WQCDB-3 1971
Fish Toxicity Tests					
2010	96	Bluegill	TL_m	synthetic	WQCDB-5 1973
5500	24	Bluegill	TL_m	standard reference water	WQCDB-3 1971
4200	48	Mosquito fish	TL_m		WQCDB-3 1971
940	96	Bluegill	TL_m		WQCDB-3 1971
12 060	24	Pickerel	TL_m		WQC 1963
920	96	Mosquito fish	TL_m	turbid	WQC 1963
1941	24	*Lymnaea* sp.	TL_m	standard reference water	WQCDB-3 1971

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Microorganisms					
1337	120	*Nitzschia linearis*	TL_m	aerated, synthetic seawater	WQCDB-5 1973
Invertebrates					
373 to 432	64	*Daphnia magna*	immobilization threshold	Lake Erie water	WQC 1963
679	24	*Daphnia magna*	TL_m	standard	WQCDB-3 1971
1250 to 1860	"a few"	*Daphnia crustacea*	killed	various	WQC 1963
600		*Daphnia pulex*	no effect	-	NRCC 1977
127		*Leptodora kindtii*	immobilization threshold	Lake Erie	WQC 1963
640		*Cyclops vernalis*	immobilization threshold	20 to 25°C	WQC 1963
1200		Vector snail (*Biomorpholaria alexandrina*)	tolerance limit	-	WQCDB-3 1971
1800		Vector snail (*Bulinus truncatus*)	tolerance limit	-	WQCDB-3 1971
940	96	Snail (*Physa heterostropha*)	TL_m	-	WQC 1963
Saltwater Species					
47 700	96	Three-spine stickleback (*Gasterosteus aculeatus*)	LC_{50}	static test with simulated brine, 5°C	Hutcheson 1983
52 500	96	Polychaete worm (*Nephtys incisa*)		static test with simulated brine, 5°C	Hutcheson 1983
54 800	120	Blue mussel (*Mytilus edulis*)		static test with simulated brine, 5°C	Hutcheson 1983

6.3 Livestock Toxicity

No adverse effects were noted in sheep fed 116 g KCl/d in drinking water (WQC 1963). Chicks fed potassium chloride in water (2500 mg/L) for 10 days experienced 1/3 mortality (WQC 1963). Dairy cows fed potassium acetate equivalent to 1.6 kg potassium per day showed no toxic effects; however, calves showed toxic effects at lower levels. Sheep are quite tolerant of potassium, even at higher levels (NRCC 1977).

6.4 Aquatic Studies

Srivastava (1982) investigated the effects of potash on the blood of the Indian catfish (*Meteropneustes fossils*) and found that normal runoff levels did not cause serious or irreversible effects.

6.5 Effects of Potash on Flora

A number of studies have examined the effect of potash, especially as a dust, on vegetation. A number of studies have examined the yield loss of field crops due to salinity alone or as a result of potash dust applied. In one study, dry refinery potash dust was applied to wheat and barley which suffered significant yield reductions at levels of 35 g/m^2. Another study showed that potash salt dust applied at 224 g/m^2 significantly reduced wheat yields. At levels of 1120 g/m^2, the yield was reduced by one half under high moisture conditions and by one quarter under low moisture conditions (NRCC 1977). One researcher calculated that for each gram of dust applied, wheat yields fell 0.01 g per plant. Field experiments revealed that wheat, barley and rye yields were not suppressed by applications of less than 1120 g/m^2 whereas another experiment showed that 250 g/m^2 produced decreased yields. The difference between these two experiments was attributed to the differences in the natural salinity of the soil and drainage (Hart 1983). In another experiment, 1790 and 3360 g/m^2 brought the yields of wheat down by 21 and 53 percent, respectively, and of rapeseed down 19 and 25 percent, respectively. Application of dolomite lime at 11 percent and 22 percent to these two plots brought yields back to normal (Redmann 1978). In still another experiment, rapeseed did not suffer a yield loss at 52 g/m^2 and subsequently at 75 g/m^2, but suffered considerable leaf necrosis (NRCC 1977).

Relative humidity was found to be an important factor in crop damage by dust; 55 percent was the critical value. At relative humidities below 55 percent, little damage was observed at low applications; above this value, severe damage was noted. High doses of the applied dust resulted in high levels of the chloride ion (Cl^-) in both the foliage and grain. Similar elevated levels are observed on crops adjacent to potash mines. Barley and

oats appear to accumulate more chloride than does wheat. In wheat, it has been shown that the accumulation results from foliage contact rather than from soil uptake, whereas in barley and oats the primary source of chloride is from the soil (NRCC 1977). Damage in most studies showed good correlation with chloride amount. Chloride content of 0.23 percent (dry weight) in the leaves correlated with little damage. Plants with higher levels showed greater damage (Redmann 1978).

Research at the University of Saskatchewan has shown that chloride doses as low as 50 g/m^2 per month can injure woody species and that the threshold for injury may be as low as one-tenth this amount. Plants exposed to excess airborne salts display symptoms such as marginal or tip burn in leaves, interveinal or marginal chlorosis, premature leaf drop and die-back of branch tips. Seasonally, trees are most sensitive in the springtime, just after the temperature rises above freezing. The difference between foliar and root uptake is marked. Foliar uptake is more rapid and more intermittent than root uptake; species tolerant of soil salinity may be injured by potash applied to leaves. In addition, as noted above, foliar uptake is higher at high atmospheric humidity (Redmann 1983).

Woody plants are more sensitive to excess chloride than are herbaceous species. The dustfall threshold for aspen is 5.0 g/m^2 per month. In deciduous woody species, the youngest leaves are the most sensitive while in conifers, year-old needles are the most sensitive. White spruce is considered sensitive while Russian olive and Colorado spruce are considered resistant (Redmann 1983). Experiments have shown that conifer needles die back from their tips when exposed to potash dust. The following is a list of trees in decreasing sensitivity (or increasing resistivity) to potash dust: Manitoba maple, American elm, willow, green ash, caragana, pine, lilac, poplar, and Colorado spruce (Redmann 1978).

6.6 Degradation

Potassium chloride does not biodegrade; however, potassium is a nutrient and will ultimately be absorbed by organisms.

6.7 Long-term Fate and Effects

Bioaccumulation and food chain concentration do not occur.

7 HUMAN HEALTH

There is very little information in the published literature pertaining to the potential toxic effects of potassium chloride. Some ingestion information is available, primarily relating to the pharmaceutical applications of the purer potassium chloride in humans.

Potassium is an essential element and total body potassium is closely regulated by the kidney. Humans tolerate a wide range of potassium intake; however, potassium poisoning can occur if excess amounts are ingested or if the kidneys are impaired.

No exposure standards were found in the literature, and no major toxicity reviews or monographs were found. No information pertaining to mutagenic, teratogenic or carcinogenic effects of potassium chloride was found in the literature sources reviewed. Potassium chloride has been included in the EPA TSCA Inventory (RTECS 1979). The toxicological data summarized here have been extracted from reliable standard reference sources.

7.1 Recommended Exposure Limits

Guideline (Time)	Origin	Recommended Level	Reference
Other Human Toxicities			
TLV		Nuisance dust - 10 mg/m^3 or 5 mg/m^3 of respirable dust	TLV 1983
LD_{LO} (2 d)	-	938 mg/kg (infant)	RTECS 1979
Probable Lethal Dose	-	0.5 to 5 g/kg	TDB (on-line) 1981

7.2 Irritation Data

7.2.1 Skin Contact. No data.

7.2.2 Eye Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rabbit		
500 mg (24 h)	Severe irritation	RTECS 1979

7.3 Threshold Perception Properties

7.3.1 Odour. Odour Characteristics: odourless (Kirk-Othmer 1982)

7.3.2 Taste.

Parameter	Media	Concentration	Reference
Taste Detection Threshold	In water	0.0170 moles/L	ASTM 1980
Taste Detection Threshold	In water	0.320 g/100 mL	ASTM 1980

7.4 Long-term Studies

7.4.1 Inhalation (of dust).

Exposure Level (and Duration)	Effects	Reference
60-2000 mg/m^3 (repeated and long exposures)	Perforation of nasal septum has occurred in underground miners	NRCC 1977

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
Acute Exposure		
SPECIES: Human		
About 40 to 50 g (KCl)	An 84-year-old woman with a history of many bouts of congestive failure was in apparently controlled cardiac status when she committed suicide by ingesting liquid potassium supplement. The estimated dose, 540 to 720 meq of potassium, is about equal to 40 to 50 g KCl	TDB (on-line) 1981

Exposure Level (and Duration)	Effects	Reference
0.5 to 5 g/kg	Probable oral lethal dose for humans is between 30 mL and 473 mL for a 70 kg person. Acute potassium intoxication by mouth is rare because large single doses usually induce vomiting. In addition, in the absence of pre-existing kidney damage, potassium is rapidly excreted	TDB (on-line) 1981
938 mg/kg (2 d)	LD_{LO} for an infant	RTECS 1979
SPECIES: Guinea Pig		
2500 mg/kg	LD_{50}	RTECS 1979
SPECIES: Rat		
2430 mg/kg	LD_{LO}	RTECS 1979
SPECIES: Mouse		
383 mg/kg	LD_{50}	RTECS 1979
SPECIES: Animal (unspecified)		
Unspecified (24 h)	Animals died from respiratory failure sometimes following convulsions and accompanied by gastroenteritis, dehydration of organs, and early renal tubular necrosis. Survivors had anorexia, polydipsia, polyuria, fever, convulsive movements, and gastrointestinal disturbances	TDB (on-line) 1981

7.4.3 Subcutaneous.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Pig		
2210 mg/kg	LD_{LO}	RTECS 1979

Exposure Level (and Duration)	Effects	Reference
SPECIES: Guinea Pig		
2550 mg/kg	LD_{LO}	RTECS 1979

7.4.4 Mutagenicity, Teratogenicity and Carcinogenicity. No data.

7.5 Symptoms of Exposure

7.5.1 Inhalation.

1. Slight irritation of nose (Lefèvre 1980).
2. Sneezing (Lefèvre 1980).

7.5.2 Ingestion.

1. Listlessness (TDB (on-line) 1981).
2. Abdominal discomfort (TDB (on-line) 1981).
3. Nausea (TDB (on-line) 1981).
4. Vomiting (TDB (on-line) 1981).
5. Gastrointestinal tract irritation (TDB (on-line) 1981).
6. Diarrhea (TDB (on-line) 1981).
7. Generalized weakness (TDB (on-line) 1981).
8. Vertigo (TDB (on-line) 1981).
9. Paresthesia (TDB (on-line) 1981).
10. Mental confusion (TDB (on-line) 1981).
11. Flaccid paralysis (TDB (on-line) 1981).
12. Hypotension (TDB (on-line) 1981).
13. Cardiac arrhythmia and heart block (TDB (on-line) 1981).
14. Death (TDB (on-line) 1981).

7.5.3 Skin Contact. No data.

7.5.4 Eye Contact. No data.

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Potassium Chloride (Potash) with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Fire											•		Sublimes at 1500°C	Sax 1979
SPECIFIC CHEMICALS														
Bromine Trifluoride										•			Rapidly attacked by potassium chloride	NFPA 1978
Sulphuric Acid and Potassium Permanganate		•											Mixture of trace explodes	NFPA 1978

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been presented essentially unchanged - in so doing, it is recognized that there may be discrepancies between different sources of information. It is recognized that countermeasures are dependent on the situation, and thus what may appear to be conflicting information may in fact be correct for different situations. The following procedures should not be considered as Environment Canada's recommendations.

9.1.1 Fire Concerns. Potash is a nonflammable material and does not support combustion (Kerr-McGee MSDS 1980).

9.1.2 Spill Actions, Cleanup and Treatment.

9.1.2.1 General. Stop or reduce discharge of material if this can be done without risk.

9.1.2.2 Spills on land. If spilled in the solid form, shovel material into containers for recovery or disposal (ERG 1980; Kerr-McGee MSDS 1980). If spilled in the solution form, contain if possible, adsorb on sand or other noncombustible absorbent material and shovel into containers (with cover) for disposal (ERG 1980).

To restore agricultural land to normal productivity, dolomite lime may be applied at a rate of about one-half the amount of residual potash remaining in the soil (Redmann 1978).

9.1.2.3 Spills on water. Contain contaminated liquid and remove for treatment if possible. Reverse osmosis can remove potash from water. If containment and removal are not possible, ensure that the concentration is diluted to become nontoxic to aquatic life.

9.1.3 Disposal. Waste potash must never be discharged directly into sewers or surface waters. It can be disposed of in a chemical landfill site with environmental authorities' approval (Kerr-McGee MSDS 1980).

9.1.4 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spilled material is known to be potash, dust respirators may be worn if necessary for protection (Kerr-McGee MSDS 1980).

10 PREVIOUS SPILL EXPERIENCE

This section contains information on previous spill experience which will be useful to readers in understanding spill response and countermeasures. Only those which meet the criteria are included, and thus, the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for the analysis of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Potassium Chloride in Air

11.1.1 Atomic Absorption Spectrophotometry (NIOSH 1979). A range of 4.2 to 84 $\mu g/m^3$ (1 to 30 ppb) of potassium chloride as potassium may be determined using atomic absorption spectrophotometry.

A known volume of air is drawn through a 37 mm diameter cellulose-ester membrane filter of 0.8 μ pore size, housed in a two-piece filter cassette holder. A sample size of 180 L at a flow rate of 1.5 L/min is recommended.

The filter sample is transferred to a clean 125 mL beaker and 6.0 mL of 10 percent nitric acid are added. The beaker is covered with a watch glass and heated to 165°C on a hotplate in a fume hood. The heating is continued until the filter dissolves and a slightly yellow solution is produced. The watch glass is rinsed with 10 percent nitric acid and the rinsings are added to the beaker. The sample is then evaporated to dryness on a steam bath. A further 5 mL of 10 percent nitric acid are added and the sample heated at 100°C for 5 minutes. The solution is quantitatively transferred to a 10 mL volumetric flask. A 0.2 mL volume of 50 mg/mL cadmium sulphate is added to the flask. The sample is taken to volume with 10 percent nitric acid.

A 2 mL volume of the sample is aspirated into the flame of a suitable atomic absorption spectrophotometer equipped with air-acetylene and nitrous oxide-acetylene burner heads, a deuterium hollow cathode lamp, two stage regulators for air, acetylene and nitrous oxide as well as heating tape and rheostat for nitrous oxide regulator. The absorbance is determined at 766.5 nm and the concentration is determined using a calibration curve.

11.2 Qualitative Method for the Detection of Potassium Chloride in Air

Potassium chloride in air may be determined as potassium by a flame test. The sample is collected as in Section 11.1.1 and digested. A clean platinum wire is dipped into a portion of sample and placed into the hottest part of a bunsen burner flame. A pale violet flame colour with slight intensity indicates potassium (Welcher 1955).

11.3 Quantitative Method for the Detection of Potassium Chloride in Water

11.3.1 Flame Photometry (ASTM 1979). A range of 1 to 100 mg/L (ppm) of potassium chloride as potassium may be determined using flame photometry. A minimum of 2 L of representative sample is collected in an appropriate container. If the sample is turbid, it is filtered through a 11 cm ashless filter paper. The sample is aspirated into the flame of a suitable flame photometer. The emission intensity is measured at 768 nm and the sample concentration determined from a calibration graph.

11.4 Qualitative Method for the Detection of Potassium Chloride in Water

Potassium chloride in water may be determined as potassium by a flame test. The sample is collected as in Section 11.3.1. A clean platinum wire is dipped into a portion of sample and placed into the hottest part of a bunsen burner flame. A pale violet flame colour with slight intensity indicates potassium (Welcher 1955).

11.5 Quantitative Method for the Detection of Potassium Chloride in Soil

11.5.1 Flame Photometry (Hesse 1972). A variable range, depending on the aliquot of extract atomized, of potassium chloride as potassium may be determined using flame photometry.

A 1.0 g sample of 0.15 mm soil (screened through a 0.15 mm sieve), accurately weighed, is placed in a platinum crucible and moistened with two drops of water. A 5 mL volume of hydrofluoric acid and 0.5 mL of 60 percent perchloric acid are added to the sample. The crucible is nearly completely covered with its lid and the mixture heated to 200°C until the liquid has evaporated. The crucible is allowed to cool and 5 mL of 6 M

hydrochloric acid are added. The crucible is then half filled with water. The contents are gently boiled for 5 minutes. The dissolved residue in the crucible is transferred to a 100 mL volumetric flask and diluted to volume.

The sample is aspirated into the flame of a suitable flame photometer at a wavelength approximating 768 nm and the sample concentration determined from a calibration graph.

11.6 Qualitative Method for the Detection of Potassium Chloride in Soil

Potassium chloride in soil may be determined as potassium by a flame test. The sample is collected and digested as in Section 11.5.1. A clean platinum wire is dipped into a portion of sample and placed into the hottest part of a bunsen burner flame. A pale violet flame colour with slight intensity indicates potassium (Welcher 1955).

12 REFERENCES AND BIBLIOGRAPHY

12.1 References

AAR 1983: Association of American Railroads, personal communication, Meier, G. (January, 1983).

ASS: Atlas Steel, Atlas Stainless Steels, Toronto, Ontario, not dated.

ASTM 1979: American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31, Water, Philadelphia, PA, D1428C, D1192, D3370 (1979).

ASTM 1980: American Society for Testing and Materials, Compilation of Odor and Taste Threshold Values Data, Philadelphia, PA, ASTM Data Series DS-48A (1980).

Bailar 1973: Bailar, J.C. (ed.), Comprehensive Inorganic and Metal-Organic Compounds, Pergamon Press, London (1973).

CBG 1980: Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, Vol. 64, No. 9, Don Mills, Ontario (December, 1980).

CCP 1982: "Potash", Canadian Chemical Processing, Vol. 66, No. 3, p. 18 (May 14, 1982).

CCPA 1981: The Canadian Chemical Producers' Association, List of Members, Toronto, Ontario (October, 1981).

CDS 1967: National Association of Corrosion Engineers, Corrosion Data Survey, Houston, TX (1967).

CLC 1974: Association of American Railroads, The Car and Locomotive Cyclopedia of American Practices, published by Simmons-Boardman, Omaha, NB (1974).

Corpus 1984: Corpus Information Services Ltd., "Potash", Chemical Product Profiles, Don Mills, Ontario (February 15, 1984).

CRC 1980: Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, Cleveland, OH (1980).

DCRG 1978: Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, MI (1978).

Dillon 1982: Dillon, M.M., Survey of Countermeasures Systems for Hazardous Material Spills, Environment Canada, Ottawa, Canada (1982).

DPLV 1972: Dow Chemical Company, Dow Plastic Lined Valves, Midland, MI (1972).

DPPED 1967: DOM-X, DOM-X Plastic Pipe Engineering Data, Toronto, Ontario (1967).

Eco/Log 1981: "Environmental Studies to Begin For First Manitoba Potash Mine", Eco/Log, 9, No. 20 (29 May, 1981).

ERG 1980: U.S. Department of Transportation, Hazardous Materials, 1980 Emergency Response Guidebook, Research and Special Programs Administration, Materials Transportation Bureau, Washington, DC (1980).

FC 1981: Farm Chemicals, "Do You Know Your Fertilizers - Part 6 - Potash", pp. 62-66 (October, 1981).

FKC 1975: Lowenheim, F.A. and M.K. Moran, Faith, Keye's and Clark's Industrial Chemicals, Wiley-Interscience, New York, NY (1975).

GF: GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, CA, not dated.

GPP: Uniroyal Inc., Guide to Polymer Properties, Mishawaka, IN, not dated.

Hart 1983: Hart, R.T., "The Effect of Potash Dust Emissions on Vegetation", POTASH '83, pp. 835-839 (1983).

Hesse 1972: Hesse, P.R., A Textbook of Soil Chemical Analysis, Chemical Publishing Co. Inc., New York, NY, pp. 143, 328 (1972).

HIS 1969: Hydraulic Institute, Hydraulic Institute Standards, 12th edition, New York, NY (1969).

Hutcheson 1983: Hutcheson, M.S., "Toxicological Effects of Potash Brine on Bay of Fundy Marine Organisms", Marine Environ. Res., 9, pp. 237-255 (1983).

JANAF 1971: Stull, D.R., Prophet, H., JANAF Thermochemical Tables, second edition, Office of Standard Reference Data, U.S. National Bureau of Standards, Washington, DC (June, 1971).

JSSV 1979: Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, NY (1979).

Kerr-McGee Bulletin: Kerr-McGee Chemical Corporation, Industrial Bulletin, Oklahoma City, OK, not dated.

Kerr-McGee TIS 1979: Kerr-McGee Chemical Corporation, "Potassium Chloride", Technical Information Sheet, Bulletin 1031 H, Oklahoma City, OK (August, 1979).

Kerr-McGee MSDS 1980: Kerr-McGee Chemical Corporation, Material Safety Information Sheet, "Potash, Potassium Chloride", Oklahoma City, OK (October, 1980).

Kerr-McGee MSI 1980: Kerr-McGee Chemical Corporation, Material Safety Information, Oklahoma City, OK (October, 1980).

Kirk-Othmer 1982: Kirk-Othmer Encyclopedia of Chemical Technology, third edition John Wiley & Sons, New York, NY (1982).

Lange's Handbook 1979: Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th edition, McGraw-Hill Book Company, New York, NY (1979).

Lefèvre 1980: Lefèvre, M.J. and E.O. Becker, First Aid Manual for Chemical Accidents - For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson, and Ross, Inc., Stroudsburg, PA (1980).

Linke 1965: Linke, W.F., Solubilities of Inorganic and Metal-Organic Compounds, American Chemical Society, Washington, DC (1965).

MWPP 1978: Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec (1978).

NFPA 1978: National Fire Protection Association, Fire Protection Guide on Hazardous Materials, seventh edition, Boston, MA (1978).

NIOSH 1979: National Institute for Occupational Safety and Health, Manual of Analytical Methods, second edition, Vol. 5, P & CAM 173, Cincinnati, OH (August, 1979).

NRCC 1977: NRCC Associate Committee on Scientific Criteria for Environmental Quality, The Effects of Alkali Halides in the Canadian Environment, National Research Council Canada, Ottawa, Ontario, NRCC No. 15019 (1977).

PCS 1982: Personal Communication, International Minerals and Chemical Corporation, Toronto, Ontario (February, 1982).

Perry 1973: Perry, R.H. and C.H. Chilton, (eds.), Chemical Engineer's Handbook, fifth edition, McGraw-Hill Book Company, New York, NY (1973).

Redmann 1978: Redmann, R.E., E.H. Halstead and L.J. Townley-Smith, "Airborne Salt from Potash Mines: Impacts on Trees and Soils", Proceedings of the Canadian Land Reclamation Association, 4th Conference, Saskatchewan (1978).

Redmann 1983: Redmann, R.E., "Resistance of Plant Species to Airborne Residual Salts from Potash Refineries", POTASH '83, pp. 823-827 (1983).

Rosenstock 1977: Rosenstock, H.M., K. Draxl, B. Steiner and J.T. Herron, Energetics of Gaseous Ions, National Bureau of Standards, Washington, DC (1977).

RTECS 1979: Lewis, R.J. and R.L. Tatken, Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH (September, 1980).

Sask. APCA 1978: Air Pollution Control Act, R.S. Saskatchewan 1978, C.A-17, Schedule 1, Ambient Air Quality Standards (1978).

Sax 1979: Sax, N.I., Dangerous Properties of Industrial Materials, fifth edition, Van Nostrand Reinhold Company, New York, NY (1979).

Scott 1979: Scott's Industrial Directory of Ontario Manufacturers, 12th edition, Penstock Directories Limited, Oakville, Ontario (1979).

Srivastava 1982: Srivastava, P.N. and A.S. Narain, "Leucocytic and Haemostatic Reactions of the Indian Catfish, *Meteropneustes fossils*, Subjected to Environmental Pollution by Sewage, Fertilizers and Insecticides", acta Pharmacol. Toxicol., 50, p. 13 (1982).

TCM 1979: General American Transportation Corporation, Tank Car Manual, Chicago, IL (May, 1979).

TDB (on-line) 1981: Toxicity Data Base, Toxicology Information On-Line, Available from National Library of Medicine, Washington, DC (1981).

TDGC 1980: Transport Canada, Transportation of Dangerous Goods Code, Vol. 1 (Lists), Vol. 2, Ottawa, Canada (June, 1980).

TLV 1983: American Conference of Governmental Industrial Hygienists, TLV•s Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1983-84, Cincinnati, OH (1983).

TPS 1978: GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, CA (1978).

Ullmann 1975: Ullmanns Encyklopaedie der technischen Chemie, Verlag Chemie, Weinheim (1975).

Welcher 1955: Welcher, F.J. and R.B. Hahn, Semimicro Qualitative Analysis, D. Van Nostrand Co., Inc., Princeton, NJ, p. 432 (1955).

WQC 1963: McKee, J.E. and H.W. Wolf, Water Quality Criteria, second edition, Resources Agency of California, State Water Quality Control Board (1963).

WQCDB-3 1971: Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Water Quality Office, Washington, DC, Vol. 3 (May, 1971).

WQCDB-5 1973: Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Water Quality Office, Washington, DC, Vol. 5 (September, 1973).

12.2 Bibliography

Air Pollution Control Act, R.S. Saskatchewan 1978, C.A-17, Schedule 1, Ambient Air Quality Standards (1978).

American Conference of Governmental Industrial Hygienists, TLV•s Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1983-84, Cincinnati, OH (1983).

American Society for Testing and Materials, Compilation of Odor and Taste Threshold Values Data, Philadelphia, PA, ASTM Data Series DS-48A (1980).

American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31, Water, Philadelphia, PA, D1428C, D1192, D3370 (1979).

Association of American Railroads, personal communication, Meier, G. (January, 1983).

Association of American Railroads, The Car and Locomotive Cyclopedia of American Practices, published by Simmons-Boardman, Omaha, NB (1974).

Atlas Steel, Atlas Stainless Steels, Toronto, Ontario, not dated.

Bailar, J.C. (ed.), Comprehensive Inorganic and Metal-Organic Compounds, Pergamon Press, London (1973).

The Canadian Chemical Producers' Association, List of Members, Toronto, Ontario (October, 1981).

Corpus Information Services Ltd., "Potash", Chemical Product Profiles, Don Mills, Ontario (February 15, 1984).

Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th edition, McGraw-Hill Book Company, New York, NY (1979).

Dillon, M.M. Survey of Countermeasures Systems for Hazardous Material Spills, Environment Canada, Ottawa, Canada (1982).

DOM-X, DOM-X Plastic Pipe Engineering Data, Toronto, Ontario (1967).

Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, MI (1978).

Dow Chemical Company, Dow Plastic Lined Valves, Midland, MI (1972).

"Environmental Studies to Begin For First Manitoba Potash Mine", Eco/Log, 9, No. 20 (29 May 1981).

Farm Chemicals, "Do You Know Your Fertilizers - Part 6 - Potash", pp. 62-66 (October, 1981).

General American Transportation Corporation, Tank Car Manual, Chicago, IL (May, 1979).

GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, CA, not dated.

GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, CA (1978).

Hart, R.T., "The Effect of Potash Dust Emissions on Vegetation", POTASH '83, pp. 835-839 (1983).

Hesse, P.R., A Textbook of Soil Chemical Analysis, Chemical Publishing Co. Inc., New York, NY, pp. 143, 328 (1972).

Hutcheson, M.S., "Toxicological Effects of Potash Brine on Bay of Fundy Marine Organisms", Marine Environ. Res., 9, pp. 237-255 (1983).

Hydraulic Institute, Hydraulic Institute Standards, 12th edition, New York, NY (1969).

Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, NY (1979).

Kerr-McGee Chemical Corporation, Industrial Bulletin, Oklahoma City, OK, not dated.

Kerr-McGee Chemical Corporation, "Potassium Chloride", Technical Information Sheet, Bulletin 1031 H, Oklahoma City, OK (August, 1979).

Kerr-McGee Chemical Corporation, Material Safety Information Sheet, "Potash, Potassium Chloride", Oklahoma City, OK (October, 1980).

Kerr-McGee Chemical Corporation, Material Safety Information, Oklahoma City, OK (October, 1980).

Kirk-Othmer Encyclopedia of Chemical Technology, third edition, John Wiley & Sons, New York, NY (1982).

Lefèvre, M.J. and E.O. Becker, First Aid Manual for Chemical Accidents - For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson, and Ross, Inc., Stroudsburg, PA (1980).

Lewis, R.J. and R.L. Tatken, Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH (September, 1980).

Linke, W.F., Solubilities of Inorganic and Metal-Organic Compounds, American Chemical Society, Washington, DC (1965).

Lowenheim, F.A. and M.K. Moran, Faith, Keye's and Clark's Industrial Chemicals, Wiley-Interscience, New York, NY (1975).

McKee, J.E. and H.W. Wolf, Water Quality Criteria, second edition, Resources Agency of California, State Water Quality Control Board (1963).

National Association of Corrosion Engineers, Corrosion Data Survey, Houston, TX (1967).

National Fire Protection Association, Fire Protection Guide on Hazardous Materials, seventh edition, Boston, MA (1978).

National Institute for Occupational Safety and Health, Manual of Analytical Methods, second edition, Vol. 5, P & CAM 173, Cincinnati, OH (August, 1979).

NRCC Associate Committee on Scientific Criteria for Environmental Quality, The Effects of Alkali Halides in the Canadian Environment, National Research Council Canada, Ottawa, Ontario, NRCC 15019 (1977).

Perry, R.H. and C.H. Chilton, (eds.), Chemical Engineer's Handbook, fifth edition, McGraw-Hill Book Company, New York, NY (1973).

Personal Communication, International Minerals and Chemical Corporation, Toronto, Ontario (February, 1982).

"Potash", Canadian Chemical Processing, 66, No. 3, p. 18 (May 14, 1982).

Redmann, R.E., E.H. Halstead and L.J. Townley-Smith, "Airborne Salt from Potash Mines: Impacts on Trees and Soils", Proceedings of the Canadian Land Reclamation Association, 4th Conference, Saskatchewan (1978).

Redmann, R.E., "Resistance of Plant Species to Airborne Residual Salts from Potash Refineries", POTASH '83, pp. 823-827 (1983).

Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec (1978).

Rosenstock, H.M., K. Draxl, B. Steiner and J.T. Herron, Energetics of Gaseous Ions, National Bureau of Standards, Washington, DC (1977).

Sax, N.I., Dangerous Properties of Industrial Materials, fifth edition, Van Nostrand Reinhold Company, New York, NY (1979).

Scott's Industrial Directory of Ontario Manufacturers, 12th edition, Penstock Directories Limited, Oakville, Ontario (1979).

Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, 64, No. 9, Don Mills, Ontario (December, 1980).

Srivastava, P.N. and A.S. Narain, "Leucocytic and Haemostatic Reactions of the Indian Catfish, *Meteropneustes fossils*, Subjected to Environmental Pollution by Sewage, Fertilizers and Insecticides", Acta Pharmacol. Toxicol., 50, p. 13 (1982).

Stull, D.R. and H. Prophet, JANAF Thermochemical Tables, second edition, Office of Standard Reference Data, U.S. National Bureau of Standards, Washington, DC (June, 1971).

Toxicity Data Base, Toxicology Information On-Line, Available from National Library of Medicine, Washington, DC (1981).

Transport Canada, Transportation of Dangerous Goods Code, 1 (Lists), 2, Ottawa, Canada (June, 1980).

Ullmanns Encyklopaedie der technischen Chemie, Verlag Chemie, Weinheim (1975).

Uniroyal Inc., Guide to Polymer Properties, Mishawaka, IN, not dated.

U.S. Department of Transportation, Hazardous Materials, 1980 Emergency Response Guidebook, Research and Special Programs Administration, Materials Transportation Bureau, Washington, DC (1980).

Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Water Quality Office, Washington, DC, Vol. 3 (May, 1971).

Water Quality Criteria Data Book: Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Water Quality Office, Washington, DC, Vol. 5 (September, 1973).

Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th edition, Chemical Rubber Publishing Company, Cleveland, OH (1980).

Welcher, F.J. and R.B. Hahn, Semimicro Qualitative Analysis, D. Van Nostrand Co., Inc., Princeton, NJ, p. 432 (1955).

EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immission concentration
min	minute or minimum
mm	millimetre
µg	microgram
µm	micrometre
°Be	degrees Baumé (density)
MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_c	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_s	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_c	critical temperature
TC_{LO}	toxic concentration low
Td	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
Ts	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight